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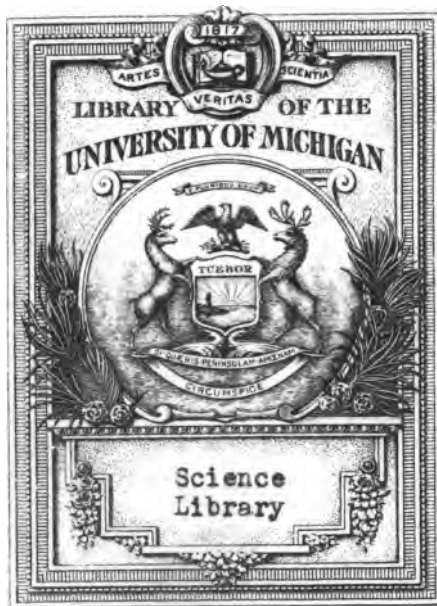
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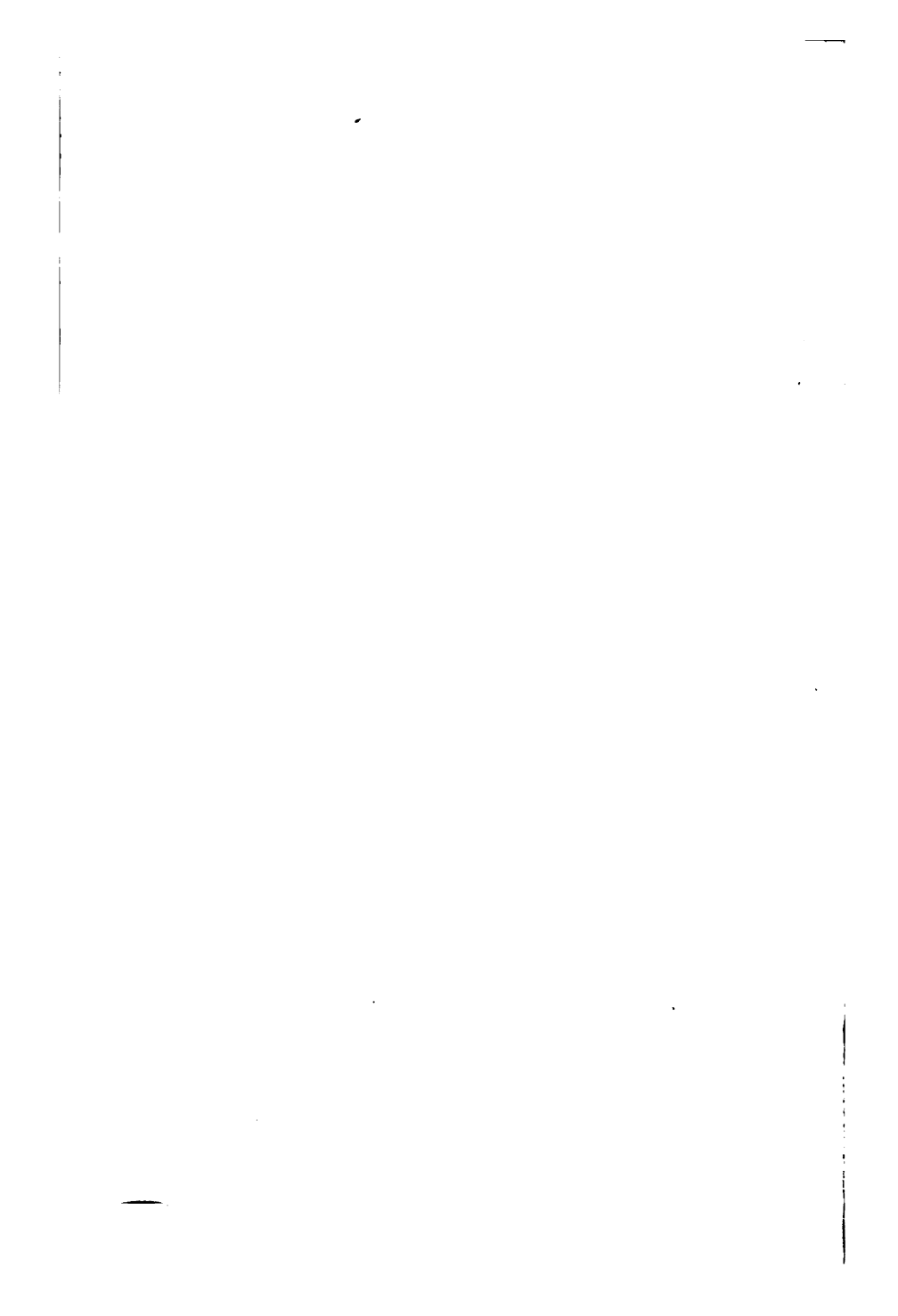
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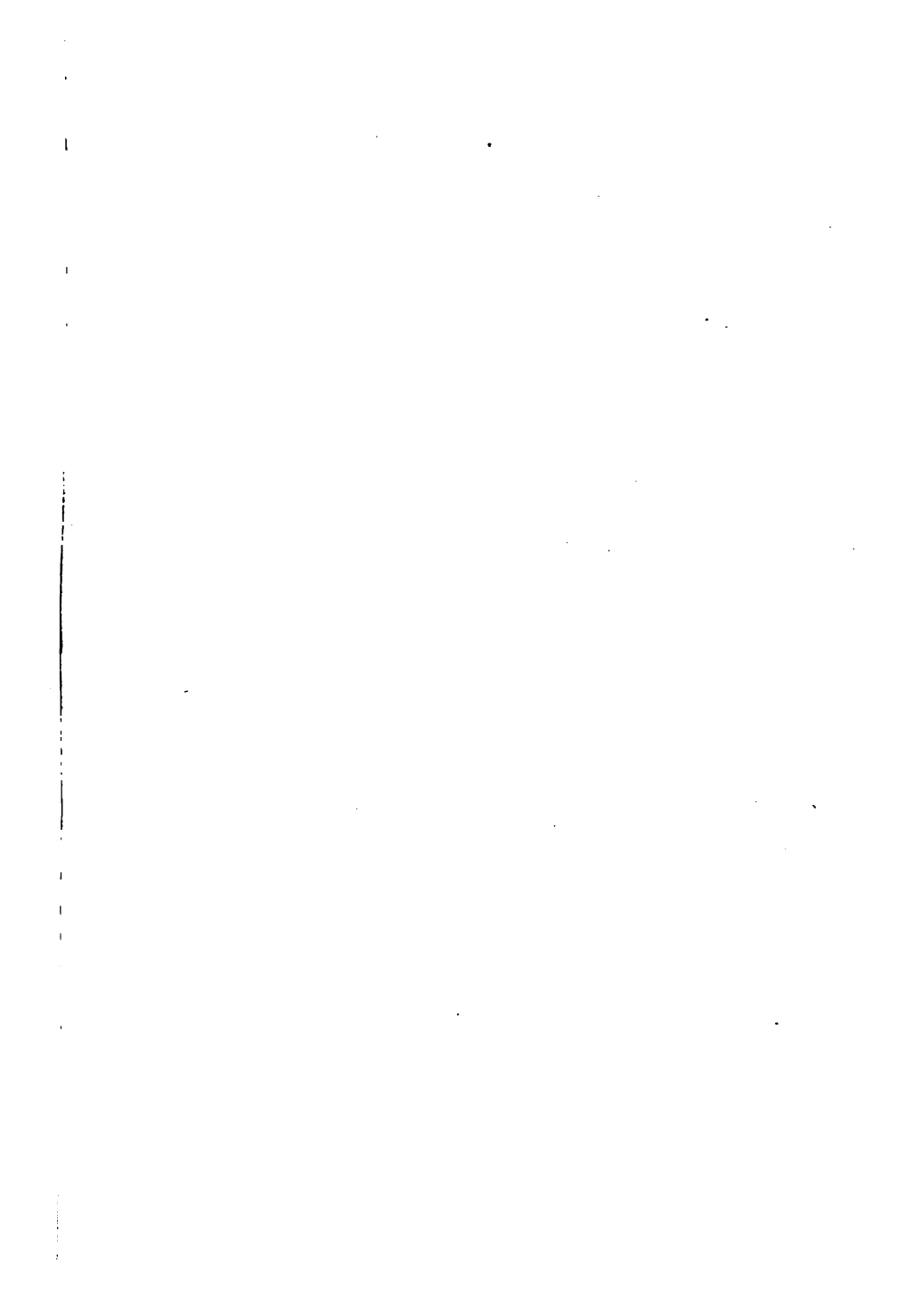
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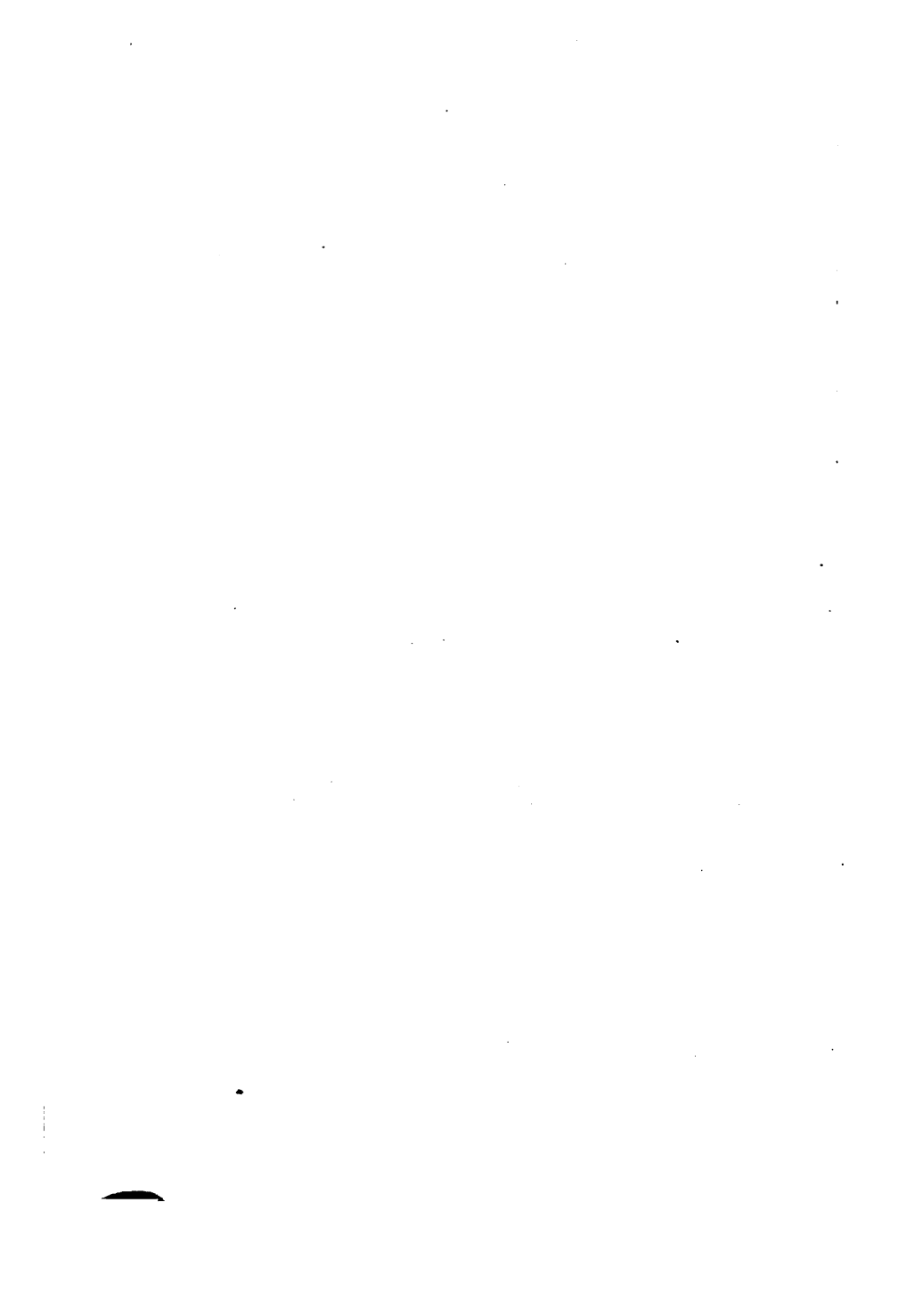
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C. W. Dodge
Revised by R. H. S.
Dec. 22, 1902

LABORATORY MANUAL

OF

BIOLOGY

BY

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AND

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Instructors in Biology, DeWitt Clinton High School, New York



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PREFACE.

It is self-evident that such an abstract and philosophical presentation of biological data, as would be suitable for advanced students, is quite out of place in a manual intended for young pupils, untrained in observation, unskilled in accurate description and easily discouraged by being left, at the outset of their studies, too much to their own devices.

The present book is not an experiment: it is the outgrowth of actual class-room experience with large classes of young pupils. Our private notes were combined and revised and the amended questions mimeographed and used in class work by five different men during the past year; the personal equation has been still more nearly eliminated through the helpful criticism of practical teachers who have read the manuscript.

The course of study for the High Schools of New York requires that botany and zoölogy (including physiology) be taught in the first year. A single volume covering both subjects is desirable in order to avoid the changing of books at the end of the first semester.

The aim of the work may be expressed in the word *training*: training the student to observe, to record his observations in verbal descriptions and drawings, to compare the forms studied and, as far as possible, to interpret structure in terms of function. We have tried

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to give the beginner enough assistance to enable him to work without constant help from the instructor: such help being an evident impossibility in large classes. This aid has, however, been reduced to a minimum, leaving the pupil something to discover for himself. Since the aim of laboratory work is often defeated by the student obtaining data from his text which he should learn by observation, the laboratory manual and the text-book should be kept separate.

The 'note and question' method of presenting the subject has the advantage of giving the student the new terms just as they are needed, while the notes and the student's answers to the given questions together make a fairly complete description of the form studied.

The interest of the young student lies perhaps more in animal and plant activities than in the static study of form; hence, as far as possible, emphasis is laid on the ecological and physiological side rather than on morphology.

The amount of microscopic work planned is rather small; as Dr. Kingsley says: "Too many beginners have been lost among cell theories and drowned in staining fluids." The microscopical studies have been generally so arranged that half the class may work with the instruments while the other half are studying the gross appearance of the given form: an important feature if there are but few microscopes available.

It is generally recognized that the arthropods, and especially the insects, form a good point of attack for the study of zoölogy. We have given several studies of insects in order that a selection may be made according to the time of year in which zoölogy is studied and the relative availability of material. Similar principles have

guided us in the work on leaves and flowers and elsewhere. The order of topics, in consequence, differs considerably from a strictly logical arrangement based on development. The frog is studied last in order that human physiology, which is taken in connection with zoölogy, may not lack an anatomical basis. In the botanical studies, the limited time devoted to cryptogams compels the omission of the hepatics and other forms interesting to the morphologist.

It is not expected, if indeed it were desirable, that all the forms given be actually taken up in any one term: many factors will determine just what selection is to be made.

The ultra scientific purist and rigorist may find cause for cavil in our use of such terms as 'exogenous' and 'endogenous.' To the critic who takes high and dry ground we simply reply that we have tried as far as possible to put ourselves in the place of the young student. To a beginner, certainly the most striking fact in the stem of a dicot is the periodic growth of the wood; and, in the stem of a monocot, the diffuse arrangement of the bundles. There is far more danger in introducing terms of which the connotation for the beginner is vague or lacking, than in using less exact words which, however, are suggested by features in the specimen actually studied. Not the sanctity of botanical nomenclature, but the sanity of the student has been our aim. There is always a suggestion of arbitrariness in words which are the outgrowth in the mind of a specialist of a vastly wider study than is possible for the novice. Technical names can be learned by the advanced student when he needs them in his further studies.

Similarly, in discussing unicellular plants and animals,

we have not sought to have our pupils learn learned cytological phrases which mean something for the practiced microtome, but which for a beginner are empty sounds.

Such classes as we conduct contain each about thirty-five students whose average age is fourteen: no one can estimate the difficulty of our task who has not attempted work under similar conditions. Nothing is more repellent to a beginner than to struggle through a manual bristling with technicalities: anything should be avoided which tends to distract attention from a careful study of the specimen.

Our prime duty as teachers is to be intelligible, and if we can make ourselves understood through giving up somewhat of purely formal accuracy, we should make the sacrifice without a shudder. The practiced thinker looks through the word to the underlying thought. Beginners in the rational life identify the word with the thing, so that to alter the phraseology sent out from the university is a dire offense, if not indeed blasphemy. We have, wherever necessary, deliberately sacrificed technical terms on the altar of pedagogic utility.

The terminology, the types chosen for study, the order in which the types are presented, the method of questioning, etc., all are to be judged from the utilitarian standpoint. The book is not ideal — neither are the conditions for which it is planned. The work here outlined is to be extended by recitations from good text books, by reference readings, by demonstrations (gross and microscopic) of related forms, by visits to botanical and zoölogical gardens and the aquarium, and especially by excursions into the country. The comparisons given in the text and the outlines for field and aquarium work have been found serviceable.

For constructive criticism, grateful acknowledgements are due to Dr. Lloyd of the Teachers College, Drs. H. E. Linville and W. A. Murrill of the De Witt Clinton High School, Miss Marie Minor, Miss A. P. Hazen and Miss Elsie Kupfer, of the Wadleigh High School.

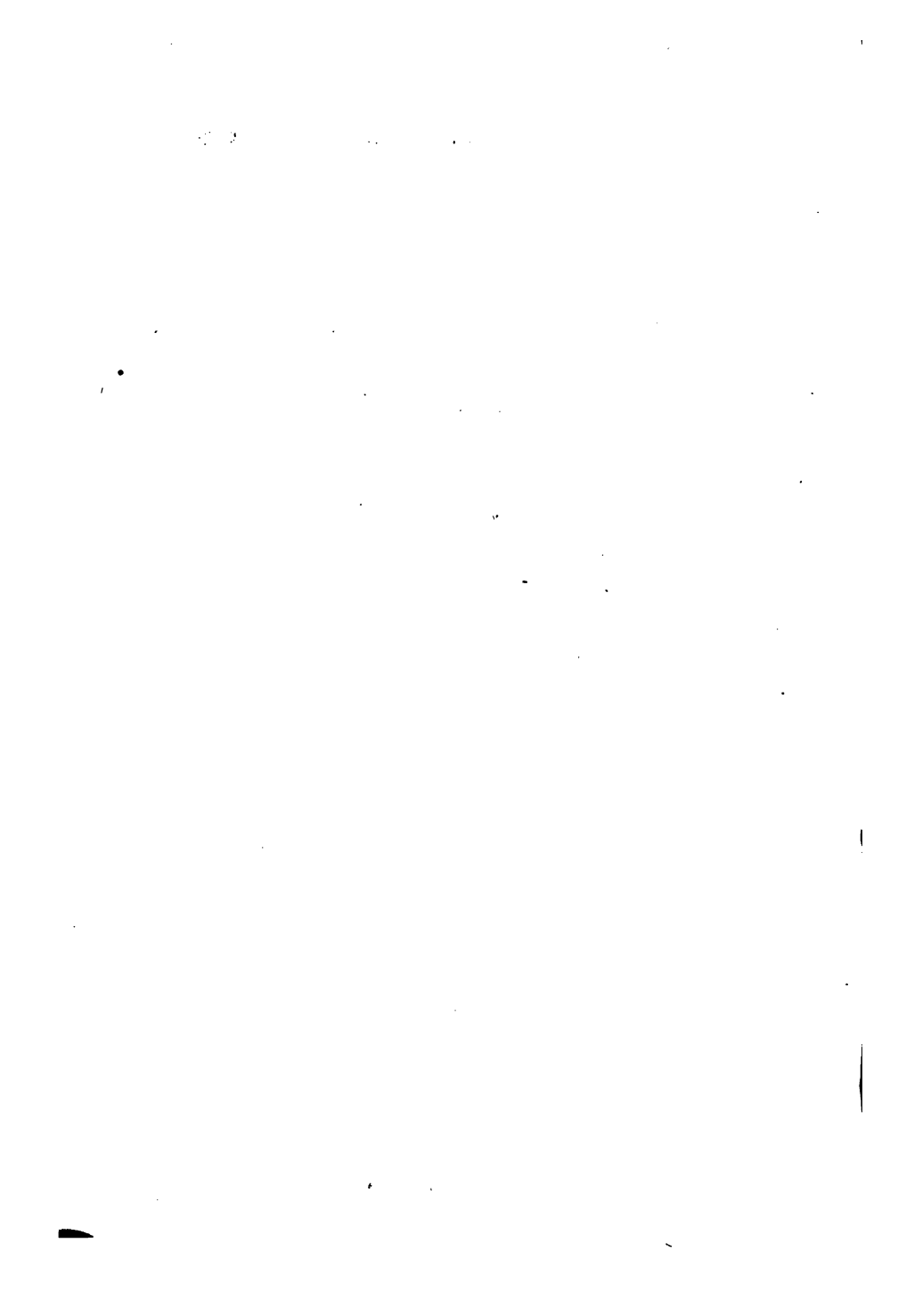
Dr. Lloyd graciously permitted us to insert, as Experiment 20, an unpublished experiment of his own.

Detailed directions for collecting and preserving material have been intentionally omitted since they may be better gathered from special books on the subject.

G. W. HUNTER, JR.

M. C. VALENTINE.

De Witt Clinton High School,
New York, May 1, 1903.



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INTRODUCTION.

DIRECTIONS FOR LABORATORY WORK.

1. Use a well-sharpened hard pencil for all laboratory work.
2. Write on only one side of the paper.
3. Leave a margin of at least one inch at the left side of each page.
4. Carefully observe the rules of correct English as to the construction of sentences. In general, avoid the use of 'it,' 'they,' etc.
5. Do not copy 'Directions': merely follow them. Copy the 'Notes' word for word and answer the 'Questions' in such a way that both notes and answers taken together may make a continuous description.
6. Never answer a question by the words 'Yes' or 'No.' Embody the question in your answer and make each answer a complete sentence.
7. Give reasons for your conclusions whenever you can do so.
8. The written work and the drawings should be kept separate.

2 *DIRECTIONS FOR LABORATORY WORK.*

9. Make your drawings to the scale indicated in the laboratory directions: thus ($\times 1$) means 'natural size.'
10. In drawing, do not sketch or shade, but make firm, continuous strokes. Let each line mean something.
11. Label carefully every important part of your drawing.
12. Neatness, legibility and accuracy go far toward making your laboratory work acceptable.

THE MICROSCOPE.

1. *Note.*—The MICROSCOPE, an instrument for making small objects appear larger, comprises two parts: the STAND and the LENSES.
2. *Note.*—The stand consists of the following parts: FOOT or BASE, PILLAR, ARM, TUBE, DIAPHRAGM, MIRROR, REVOLVING NOSE-PIECE, the COARSE and the FINE ADJUSTMENT.
 - a. Of what material is the stand made?
 - b. What are the advantages of using such material?
3. *Note.*—The stand rests upon a broad BASE or FOOT.
 - a. What is the shape of the base?
 - b. Why should the base be broad and heavy?
4. *Note.*—The jointed, vertical PILLAR gives attachment to the ARM, supporting the main TUBE of the instrument.
 - a. What are the advantages of having the pillar jointed?
5. *Note.*—Extending forward from the pillar below the arm is the STAGE, on which is placed the object to be examined.
 - a. Describe the location of the perforation in the stage.
 - b. What is its use?
 - c. What is the use of the revolving wheel, or DIAPHRAGM, pivoted to the stage?
6. *Note.*—Below the stage is a movable bar carrying the MIRRORS or reflectors.
 - a. In how many different directions can you move the mirrors?
 - b. What is the advantage of having them movable?
 - c. What kind of surface do the mirrors respectively show?
 - d. What is the use of the mirrors?

7. *Note.*—A hollow cylinder containing two lenses fits into the upper end of the tube. It is called the **EYE PIECE** or **OCULAR**.

a. Why is the name 'eye piece' applied?

8. *Note.*—Small brass cases, each containing several lenses, are attached to the tube at its lower end: they are the **OBJECT LENSES** or **OBJECTIVES**.

a. Why is the name 'objective' given to these lenses?

b. How many objectives are there in your microscope?

9. *Note.*—The **Low Power** (a slightly magnifying objective) has a short and broad case. The **HIGH POWER** objective has a long and narrow case.

a. What fractional numbers do you find on the case of the high and the low power objectives, respectively?

10. *Note.*—The objectives are attached to a revolving device, the **NOSE PIECE**.

a. What are the advantages of a revolving nose piece?

11. *Note.*—To obtain a clear image of the object under examination, we must be able to vary the distance between the lenses and the object; that is, to **FOCUS** the instrument. The microscope is brought into focus by slightly turning either of the large wheels placed at the top of the arm near the tube.

a. Why are these wheels called the **COARSE ADJUSTMENT**? (Turn one of them gently!)

b. What movement results?

12. *Note.*—The milled head of the **FINE ADJUSTMENT** is found at the top of the pillar.

a. Carefully turn the fine adjustment back and forth. (No more than half a turn in either direction!) Why is this adjustment called 'fine'?

CAUTIONS AND HINTS.

1. Do not touch either lenses or mirrors.
2. Do not rest either your arm or your head on the instrument.
3. Never make more than half a turn either way with the fine adjustment.
4. Get a fairly clear image with the coarse adjustment: use the fine adjustment only to complete the operation of focusing.
5. An object to be viewed with the compound microscope should be very thin and transparent.

Drawing. — Microscope from the side ($\times \frac{1}{2}$). Label the parts named in Note 2.

PRELIMINARY PRACTICE WITH THE
MICROSCOPE.

Materials. — Slides, cover glasses, free hand sections of potato tuber stained with iodine solution, compound microscope.

Directions for Mounting Sections and Adjusting Microscopes:

1. Place the given section on a slide in a drop of water.
2. Clean a cover glass and lower it gently over the object. (Avoid air bubbles!)
3. Put the slide on the stage with the object over the stage perforation.
4. Tilt the mirror so that the object may be well lighted.
5. By aid of the coarse adjustment bring the low power near to the object.
6. With your eye at the ocular, raise the tube from the stage till the image appears rather clearly.
7. Make the image entirely clear by a slight turn of the fine adjustment to one side or the other.

Direction. — Study the CELLULOSE (paper) walls enclosing spaces in which lie the deeply stained starch grains.

1. What color does cellulose show under the microscope?
2. What color is shown by starch grains treated with iodine?
3. While your eye is at the tube, gently move the slide away from you. How does the object appear to move?
4. In the same way, move the slide to the right and describe the apparent movement of the object.

5.
 - a. Does the right side of the image correspond to the right side of the object?
 - b. Does the upper part of the image correspond to the upper part of the object?
 - c. Does a slight movement of the object produce a slight movement of the image?
6. Explain as well as you can what you have observed in (3), (4) and (5).



PART I

BOTANICAL STUDIES

PHANEROGAMS

(Flowering Plants)

THE POLYMERIZATION OF VINYL MONOMERS

The polymerization of vinyl monomers is a process in which the monomer units are linked together to form a long chain. This process is initiated by a free radical, which attacks the double bond of the monomer, forming a new radical species.

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PRELIMINARY STUDY OF AN ENTIRE FLOWERING PLANT.

Materials. — Entire plants of *Bursa Bursa-pastoris* (or *Lepidium Virginicum*): one specimen for every two students.

1. *Note.* — The lower part of the plant, with particles of soil still clinging to it, is the **ROOT**. The root serves to take in water from the soil and to hold the plant firm.
 - a. Describe the color and shape of the root.
 - b. What advantage is gained by a plant in having roots which spread widely?
2. *Note.* — The rodlike upper part of the plant is called the **STEM**. The stem contains tubes through which liquids may pass from roots to leaves or from leaves to roots.
 - a. Compare the stem with the root in point of size.
 - b. Does the stem branch? Describe the color of the stem.
3. *Note.* — The rather broad and thin bodies attached along the sides of the stem are the **LEAVES**. The leaves give off water to the surrounding air; they breathe, take in food gases, and, in sunlight, make starch for the whole plant.
 - a. About how many leaves do you find in the specimen?
 - b. Describe the arrangement of the leaves on the stem.
 - c. Describe the shape, size and color of a leaf.
 - d. Do the leaves all have the same color, size and shape?

- e.* What advantage do the leaves gain in being raised on a stem?
4. *Note.*—The little white bodies, which apparently consist of several tiny scales, are the **FLOWERS**. It is the work of the flowers to give rise to new plants.
- a.* Where are the flowers situated?
- b.* About how many flowers does your specimen bear?
- c.* Do all the flowers appear to be of the same age? How can you tell?
5. *Note.*—The green bodies, somewhat triangular in outline, attached to the stem, are the **FRUITS**. Each fruit represents a certain part of a flower, ripened and highly developed.
- a.* Describe how a fruit is attached to the stem.
- b.* Compare the flowers with the fruits as to arrangement on the stem.
- c.* Describe accurately the shape and size of a single fruit.
6. *Note.*—Within the covering of a fruit lie **SEEDS**. Each ripe seed contains a tiny young plant and a store of food which the young plant may use till it can form food for itself.
- a.* Can you find out how the seeds escape from the ripe fruit?
- b.* Describe the size and general appearance of a seed.
7. *a.* How many fruits are there in your specimen?
- b.* About how many seeds do you find in a single ripe fruit?
- c.* How may you explain the fact that the plant you are studying is so common?

Drawings.—I. General view of entire plant ($\times \frac{1}{3}$).

II. A single leaf ($\times 2$).

III. A single fruit ($\times 5$).

SEEDS AND SEEDLINGS.

BEAN.

Materials. — Kidney beans soaked over night in water.
A few pods for demonstration. Iodin solution.

1. *a.* Describe the outline of the bean as seen from the broad side.
- b.* Describe the outline as seen from the narrow end.
2. *a.* Describe the color. Is the color uniform?
3. *Note.* — The light-colored scar or **HILUM** marks the place where the bean was attached to the pod.

a. Describe the location of the hilum more exactly.

4. *Note.* — The tiny hole near the hilum is the **MICROPYLE**.

a. Describe more exactly the location of the micropyle with reference to the hilum.

Drawings. — I. View of the broad side ($\times 2$).

 II. View of the concave edge ($\times 2$).

5. *Note.* — The coat of the seed is called the **TESTA**.

Direction. — Carefully remove the seed coat, taking especial care in the region of the hilum.

- a.* Can you find another seed coat under the testa?
- b.* Describe the thickness and consistency of each seed coat.
- c.* What do you think the purpose of the seed coats to be?

6. *Note.*—All the structures inside the seed coats are called collectively the **KERNEL**.

a. Is the kernel attached to the seed coats at any point?

7. *Note.*—The large halves of the kernel are called the **COTYLEDONS** or seed-leaves.

a. Describe a cotyledon in length, breadth, thickness and consistency.

b. Are the cotyledons exactly the same in shape and size?

8. *Note.*—Projecting beyond the cotyledons is a small rodlike body, the **HYPOCOTYL**, from the free end of which is developed the root.

a. How does the hypocotyl point with reference to the micropyle?

b. Describe the hypocotyl in size, shape, color and consistency.

Direction.—Remove carefully one cotyledon.

9. *Note.*—The delicate body lying between the cotyledons is the **PLUMULE**.

a. How many leaves do you see in the plumule?

b. How are the leaves arranged with reference to each other?

c. Describe the plumule in size, shape and color.

10. *Note.*—The entire kernel of the bean is the young plant or **EMBRYO**.

a. Of what parts does the embryo consist? (Review 7, 8 and 9.)

Demonstration.—The action of iodine solution on starch.

11. What color does starch give when treated with iodine solution?

Direction. — Answer the three following questions from half beans (cut through the hypocotyl), stained in iodine:

12. *a.* What color appears in the cotyledon?
- b.* What substance is present?
- c.* Is this substance present in the hypocotyl also?

Demonstration. — Thin sections of bean cotyledon stained with iodine and passed round the class in the demonstration microscope.

13. In what form is the food stored in the cotyledon?
14. *a.* What is the probable use of the cotyledons to the plant?
- b.* Why are the cotyledons so large?
15. Explain why beans are used by man as food.

Drawings. — III. View of half the kernel showing the plumule, hypocotyl and cotyledon ($\times 2$).

IV. View of a section across the whole bean through the hypocotyl ($\times 2$).

GRAIN OF CORN.

Materials. — Cobs of Zea Mays; separate grains soaked at least forty-eight hours; sections of grains cut perpendicularly to the flat side and moistened with weak iodine solution; cross-sections through the embryo, stained with iodine.

1. *Note.* — The so-called 'seed' of corn is really a one seeded fruit; i. e., the ripe seed enclosed in the seed vessel.

- a. How are the single fruits arranged on the fruit-stalk or cob?

- b. What can you say of the number of single fruits?

- c. What is the general outline of the fruit cluster?

2. What is the outline of a single grain as seen from the broad side?

3. Compare the end which was attached to the cob with the free end in size, shape and color.

4. Describe any differences you may note between the two broad surfaces.

5. *Note.* — The light-colored area on one side marks the position of the embryo or young plant. The rest of the grain, the ENDOSPERM, consists of food material.

- a. Describe the outline of the embryo as seen from the broad surface of the grain.

Direction. — In a longitudinal section stained with iodine solution, study the cut surface.

6. How much space is given to the embryo and the endosperm respectively?

7. What food substance is found in the endosperm?

8. *Note.* — The single cotyledon in the corn embryo is used as an organ for absorbing the endosperm.

- a. How large is the cotyledon in comparison with the rest of the embryo?

9. *Note.*—The hypocotyl points toward the sharp end of the grain; the plumule, toward the free end.

a. Compare the hypocotyl and the plumule of the embryo in shape.

b. Do you find any structure (root-sheath) present on the root that is not found on the plumule? Describe it.

10. *a.* What is the shape of the embryo in cross-section?

b. Where does the embryo lie with reference to the surface of the grain?

11. *Note.*—Plants having one cotyledon in the embryo are called MONOCOTYLEDONS; those having two are DICOTYLEDONS; and those with more than two are POLYCOTYLEDONS.

a. To which group do the bean and the corn respectively belong?

Drawings.—I. Entire grain showing the position of the embryo ($\times 4$).

II. Edge view of the entire grain ($\times 4$).

III. Cut surface of the longitudinal section ($\times 4$).

IV. Cut surface of the cross-section through the embryo ($\times 4$).

GERMINATING SEED.

Materials. — Specimens of pea, bean, squash and corn in several stages of germination.

IN THE YOUNGEST SPECIMEN.

1. *Note.* — The changes undergone by the seed from the beginning of growth until the young plant is able to take care of itself are called GERMINATION.
 - a. What change do you notice in the seed coats?
 - b. What has produced this effect?
2.
 - a. What part of the embryo first appears outside of the seed coats?
 - b. What reason can you give for this?

IN A MORE ADVANCED SPECIMEN.

3.
 - a. What part of the embryo gives rise to the root of the plant?
 - b. Describe the root in an advanced specimen.
4. Study the various specimens and describe what changes take place in the plumule.
5.
 - a. From a comparison of the different stages, determine whether the cotyledons increase in size.
 - b. Can you determine the use of the cotyledons to the developing plant?
6. Do the foliage leaves appear above or below the cotyledons?
7. Review briefly your work and tell what becomes of each of the following parts: seed coats, cotyledons, hypocotyl and plumule.

Drawings. — Make drawings from the side ($\times 2$) of at least three seedlings in different stages of germination.

Demonstration. — Pine seedlings in various stages of germination.

TABULAR COMPARISONS BETWEEN CORN,
BEAN AND PINE SEEDLINGS.

1. How many cotyledons are there?
2. Do the cotyledons contain stored food?
3. Do the cotyledons act as leaves?
4. What use do the cotyledons serve?
5. What is the comparative size of the plumule?
6. Is the hypocotyl arched at any stage? Why?

ROOTS.

PEA SEEDLING.

Materials.—A pea seedling with roots about four inches long.

1. What is the general form of the whole mass of roots?
2. *a.* In what general direction do the roots point?
b. Is this arrangement of any use to the plant? Explain.
3. Do you find a main or PRIMARY root growing directly from the stem?
4. *Note.*—The smaller roots branching from the primary root are called ROOTLETS.
 - a.* In what direction do the smaller roots point? How can you account for their general course?
 - b.* Is the branching regular?

Drawing.—Whole root as seen from the side (X 1).

Label.—Stem, primary roots and rootlets.

ROOT HAIRS.

Materials. — Seedlings of *Sinapis alba* grown on damp sponge; longitudinal section of root tip; demonstration microscope; entire roots mounted in water for the microscope.

1. *Note.* — In the living plant, tiny absorbing organs called Root HAIRS form a fringe on the rootlets.

- a. Describe the root hairs in size, shape, position and approximate number.
 - b. On which part of the root are they best developed?
 - c. On which part most abundant?
 - d. Is there any part of the root where there are no root hairs?

Direction. — Study prepared specimens under the compound microscope.

2.
 - a. Describe a single root hair in general appearance.
 - b. What can you say of the thickness of its wall?
 - c. Is it made up of more than one cell or compartment?

PREPARED LONGITUDINAL SECTION OF THE ROOT TIP.

3. *Note.* — The tip of the root is protected by a crescent-shaped mass called the Root CAP.
 - a. Does the root cap appear as firm as the root proper?
 - b. Of what use would the root cap be to a growing root?

TAPROOT.

(Modified through serving as a food storage organ.)

Materials.—Whole parsnips or carrots; roots cut longitudinally and transversely; roots placed over night in eosin or methylen blue solution and then cut transversely into small pieces; iodine solution.

IN THE ENTIRE SPECIMEN.

1. What is the general shape of a taproot?
2. *a.* Are there any rootlets?
b. Compare the rootlets with the main root in point of size.
3. Describe the structures that you find where the rootlets leave the main root.

IN THE CROSS AND THE LONGITUDINAL SECTIONS.

4. *Note.*—The outer part of the root is called the *Cortex*; the inner part is the wood.
 - a.* What is the relative thickness of cortex and of wood?
 - b.* Compare the cortex and the wood in consistency.
 5. Study sections stained in iodine.
 - a.* What kind of food does the parsnip or carrot contain?
 - b.* Where is the stored food located?
 - c.* When and how is this food of use to the plant?
 6. *a.* Through what part of the root does water pass up to the stem?
b. What relation does the stained area bear to the cortex?
c. How are the conducting tubes distributed?
- Drawings.*—I. Whole root seen from the side ($\times \frac{1}{2}$).
II. Cross-section ($\times 1$).
Label.—Conducting tubes, cortex, wood.

INDIAN CORN.

Materials.—Dry roots of *Zea Mays*.

1. Is there a primary root?
2. *Note.*—Roots which are made up of many thread-like fibers are said to be FIBROUS.
3. Do you find rootlets?
4. Are there any roots which come out from other parts of the stem (ADVENTITIOUS roots)?
 - a. What is the probable use of such roots to the corn plant?
 - b. Describe their arrangement on the stem.

Drawing.—Whole mass of roots ($\times \frac{1}{2}$).

ENGLISH IVY.

Materials. — Fresh specimens of *Hedera Helix* stems showing the aerial roots.

1. Describe the position of the roots.
2. What purpose do such roots serve in the plant?
3. What peculiarity in their structure fits them for the work they have to do?
4. Compare them in length with the other roots studied. Why this difference?

Drawing. — Small piece of ivy stem showing roots ($\times 1$).

STEMS AND BUDS.

HORSE-CHESTNUT TWIG.

Materials. — Short twigs of *Aesculus Hippocastanum* showing buds; blackboard diagrams illustrating opposite and alternate leaf arrangement.

1. Describe the general character of the bark with reference to color, surface and consistency?
2. What do you find on the free end of the twig?
3. *Note.* — The shield-shaped SCARS on the stem mark the place where the LEAF STALKS were formerly attached. The raised dots in each scar are the broken ends of bundles of vessels which carried liquids to or fro between the stem and the leaf.
 - a. How are these dots arranged?
 - b. Were the leaves alternate or opposite in arrangement?
 - c. Are the pairs of leaf-scars placed one directly above another?
4. *Note.* — The FLOWER-SCAR or FRUIT-SCAR is a rough, hollow area without raised dots, lying generally in a fork between two branches.
 - a. How many flower-scars do you find?
5. *Note.* — The part of the twig which bears the leaf-scars is called a NODE; the length of twig between any two adjacent nodes is called an INTERNODE.
 - a. Are all the internodes of the same length?

- b.* How would you explain any variation in the length of the internodes?
6. *Note.*—The very small, rough spots scattered about on the bark are the LENTICELS or breathing pores of the twig.
- a.* What can you say as to the number of lenticels?
7. *Note.*—The narrow rings on the twig are the scars left by scales of terminal buds in previous seasons. They are called BUD-SCARS.
- a.* How much space would represent a year's growth?
- b.* How many years' growth has taken place in the twig you are studying?
- c.* Does the distance between the rings vary? (Give three measurements.)
8. *a.* What structures do you find just above a leaf-scar?
- b.* Do you find the same structure above every leaf-scar?
9. Look at the bud-scar nearest to the terminal bud. Describe any differences you find in the bark on either side of this ring and give a reason for such differences.

Drawings.—I. General view of the twig ($\times 1$).

II. Leaf-scar ($\times 5$).

Label.—Terminal buds, lateral buds, leaf-scars, flower-scars, bud-scars, lenticels.

BEECH TWIG.

Materials. — Young twigs of *Fagus Americana* showing the buds.

1. *a.* Describe the general appearance of the bark.
b. Is the bark everywhere the same? Describe any variations.
2. Compare the bark in the horse-chestnut and beech.
3. *a.* Compare the leaf-scars in the two twigs as to shape, size and color.
b. Are the leaves opposite or alternate in arrangement?
c. Compare the flower-scars in the two twigs.
4. *a.* About how many lenticels are there in a single internode?
b. Compare with the horse-chestnut in this respect.
5. *a.* Do you find bud-scars?
b. How old is the twig you are studying?
6. *a.* Compare with the horse-chestnut as to the way in which the branches arise.
b. Are the lateral branches as long in the beech as in the horse-chestnut?
c. Would this difference have an effect on the appearance of the entire tree?
7. Describe any other differences between the beech and horse-chestnut.

Drawings. — I. General view of twig ($\times 1$).

II. Single leaf-scar ($\times 10$).

BLACK LOCUST, HONEY LOCUST AND CATBRIAR.

Materials. — Pieces of twig, about twelve inches in length, from *Robinia pseudacacia*, *Gleditsia triacanthos*, *Smilax rotundifolia*.

1. *Note.* — The hard, sharp projections found on the stem are called THORNS.

- a.* Describe the size, shape, consistency and location of the thorns in the black locust, the honey locust and the catbriar respectively.
 - b.* Do the thorns have any definite arrangement in the catbriar?
 - c.* Could you compare them with parts usually present in a twig?
 - d.* How are the thorns of the black locust placed with reference to the leaf stalks?
 - e.* What relation do the thorns in the honey locust bear to the leaf-scars? What parts do the thorns correspond to?
2. Of what use would thorns be to a plant?
3. (In the catbriar.) Observe the coiled, climbing organs or TENDRILS.
- a.* Describe the tendrils and explain, if you can, how they would be used by the plant.
4. By what means are the buds of the catbriar protected?
5. Explain how the climbing habit is of use to the catbriar?

Drawings. — View of a part of each twig ($\times 1$).

Label the structures shown.

TUBER.

Materials. — Clean specimens of the Irish potato; a few potatoes which have already sprouted.

1. *a.* Describe the size, shape, color and consistency of the potato.
b. Are all specimens alike in the above-mentioned characters?
2. *a.* Describe the 'eyes' with reference to size, color, shape and arrangement.
b. What plant structure does an eye represent?
3. Is the Irish potato a stem or a root? Give fully your reasons.

Drawing. — View from the side ($\times 1$).

Label. — Attached end, eyes, growing point.

EXOGENOUS STEM.

(*Cross-section of Horse-chestnut Twig.*)

Materials. — Small pieces of horse-chestnut wood cut smoothly.

1. *Q.* Describe the color, consistency and general appearance of the central PITH.
2. *Note.* — Outside of the PITH is the WOOD, containing DUCTS or tubes which run up and down the stem.
 - a. Describe the WOOD as to color and consistency.
3. *Note.* — The radiating lines seen in the wood are the MEDULLARY RAYS.
 - a. Describe the medullary rays more fully.
 - b. What do you think their function to be?
4. *a.* Describe the outer layer or BARK as seen in cross-section.
 - b. Is there more than one layer visible?
 - c. Which is tougher, BARK or WOOD?
5. How much space is occupied by bark, wood and pith, respectively?

Drawing. — Cross-section ($\times 4$).

Label. — Bark, wood, pith, medullary rays.

ENDOGENOUS STEM.

(*Cross-section of Corn-stalk.*)

Materials. — Small pieces of corn-stalk, one inch in length, preserved in 4 per cent formol.

1. **Note.** — The outer layer is called the RIND.
 - a. Which part is the harder, the rind or the pith inside it?
2. **Note.** — In the section of corn-stalk, the ducts or FIBRO-VASCULAR BUNDLES appear as dots lying in the soft pith.
 - a. Describe the fibro-vascular bundles in number and position.
 - b. Are they regularly placed with reference to each other?
 - c. Where are they most numerous?
 - d. Compare the position of the ducts in the corn-stalk and the horse-chestnut stem.
3. Do you find any medullary rays in the corn?

Drawing. — Cross-section of corn-stalk ($\times 2$).

Label. — Pith, rind, bundles.

(Cross-section of Bamboo.)

Materials. — Small pieces of bamboo stem, one inch in length.

1. How does the bamboo stem differ in structure from the cornstalk?
2. *a.* What has become of the fibro-vascular bundles in the bamboo?
b. Is there any advantage in this arrangement?
c. Which stem could support the greater weight, corn or bamboo? Why?
3. *a.* Which stem does the bamboo resemble more closely, horse-chestnut or corn?
b. Is the bamboo exogenous or endogenous? Give reasons.

Drawing. — Bamboo stem in cross-section ($\times 2$).

Label. — Rind, bundles, hollow area.

COMPARISONS BETWEEN EXOGENOUS AND ENDOGENOUS STEMS.

1. Compare the beech or horse-chestnut with the corn or bamboo in the following respects:
 - a. Position of pith.
 - b. Position of ducts.
 - c. Presence of medullary rays.
 - d. Presence of bark.
 - e. Difference between old and young stems.
2. *Note.*—Plants with EXOGENOUS stems usually have two or more cotyledons in the embryo, netted-veined leaves and the parts of the flower arranged in fours or fives.
3. *Note.*—Plants with ENDOGENOUS stems usually have a single cotyledon in the embryo, leaves with parallel veins and the parts of the flower arranged in threes.

HORSE-CHESTNUT BUD.

Materials. — Twigs of the horse-chestnut showing the terminal bud; a few opened buds.

1. *Note.* — A bud at the end of a branch is called **TERMINAL**; the buds along the sides of the branch are **LATERAL**. If a lateral bud lies in the angle or **AXIL** of a leaf it is called **AXILLARY**.
 - a. Describe the terminal bud in shape, size, color, consistency and character of surface.
 - b. What substance do you find covering the bud?
 - c. What is the use of this substance?
3.
 - a. What does the terminal bud give rise to when it develops?
 - b. How do you know this?
4.
 - a. What do the lateral buds give rise to when they develop and how do you know?
 - b. Do all of the lateral buds develop?
5. *Note.* — The bud is simply a shortened stem covered with overlapping scales, which are modified leaves.

Direction. — Cut the bud open lengthwise.

- a. What is the function of the brown, hard scales?
- b. Of what use is the cottony material?
- c. What will become of the green scales?
- d. Where are the future leaves?

Drawings. — I. Entire bud ($\times 4$).

II. Bud cut lengthwise ($\times 4$).

LEAVES.

Direction. — The teacher may place upon the board, for the use of students to whom English is a foreign language, a few labeled diagrams introducing the most common terms used in describing the various forms of margin, apex, base and general shape of leaves.

MOUNTAIN LAUREL OR ELM.

Materials. — Leaves of *Kalmia latifolia* or *Ulmus Americana*.

1. *Note.* — The thin, flat portion of the leaf is called the **BLADE**, the stalk is the **PETIOLE**, the continuation of the petiole in the blade is the **MIDRIB** and the branches of the midrib are the **VEINS**.
 - a. How long are the blade and the petiole respectively?
 - b. What is the ratio of length to width in the blade?
 - c. What is the general shape of the blade?
2. Compare the upper with the lower surface of the blade in color and character of surface.
3. *Direction.* — Refer to the board or chart and answer the following questions:
 - a. Is the leaf simple or compound? (See page 42, note 5.)
 - b. Describe the shape of the apex.
 - c. Describe the shape of the base.
 - d. Describe the margin of the leaf.

4. *Note.* — Small, leaflike bodies attached to the petiole near its base are called STIPULES.

a. Are stipules present in your specimen?

5. *Note.* — A leaf in which there is one midrib with lateral veins extending to the leaf margins, is said to be PINNATELY (feather) VEINED.

a. Is the laurel leaf pinnately veined?

b. Is it NETTED-VEINED (i. e., do the veinlets form a network)?

6. a. What is the purpose of the midrib and the veins?

b. On which surface is the midrib more prominent?
Can you tell why?

7. a. Does water wet the surface of the leaf?

b. What is the purpose of this property of leaves?

8. What are the uses or functions of leaves?

9. *Note.* — When a structure is specially fitted for some particular function it is said to be ADAPTED to that function.

a. Show how a leaf is adapted to its functions.

Drawings. — I. Entire leaf, upper surface ($\times 1$).

II. Entire leaf, under surface ($\times 1$).

Label. — Petiole, blade, midrib, veins, base, apex and margin.

MULLEIN.

Materials. — Mullein leaves of various sizes (*Verbascum Thapsus*).

1. What is the general outline of the leaf?
 2. Describe the shape of (*a*) the base, (*b*) the apex and (*c*) the margin.
 3. What kind of VENATION (arrangement of the veins) do you find?
 4. *a.* How can you tell which is the upper surface?
b. On which surface is the midrib more prominent?
 5. *Note.* — A leaf possessing the petiole is said to be STALKED; a leaf lacking the petiole is SESSILE.
a. Is the mullein leaf stalked or sessile?
 6. *a.* What is the color of the leaf?
b. To what peculiarity of structure is this color due? (Scrape a small area of the leaf.)
 7. *a.* To what dangers are leaves exposed?
b. What is the use to the leaf of its woolly covering?
- Drawing.* — Entire leaf ($\times 1$).

PINE.

Materials.—Small twigs of *Pinus* sp., bearing leaves; lenses.

1. *Note.*—The leaves or **NEEDLES** of pines occur in clusters, surrounded at the base by a **SHEATH** formed by the union of several bud scales.
 - a. How many leaves are there in a cluster?
 - b. What can you say of the length of the leaves?
 - c. What is their consistency?
2.
 - a. Describe the general outline of a pine needle.
 - b. Describe the apex as to color and shape.
 - c. Describe the margin. (Draw a needle through your fingers or use a hand lens.)
 - d. Describe the shape of a cross-section of the leaf.
3.
 - a. Does a single pine needle expose as much surface to air and sunlight as does the laurel leaf?
 - b. How does the pine tree make up for the small size of a single leaf?
4.
 - a. Is there any danger of the pine leaves shading each other?
 - b. What relation exists between the shape and size of leaves on the one hand and their number on the other?
5. *Note.*—Since the leaves of pines have no regular period of falling, the trees are always clothed with foliage, and hence are called 'evergreens.'
 - a. Do trees in our climate generally keep their leaves through the winter?
 - b. To what dangers might the leaves of a tree be exposed in the winter time?

6. Mention all the ways in which a pine needle is adapted to its severe conditions in life (in shape, size, consistency and taste).

Drawings. — I. A cluster of needles ($\times 1$).

II. Cross-section of the leaves in a single cluster ($\times 5$).

Label. — Sheath and leaves.

GERANIUM.

Materials. — Leaves of *Pelargonium zonale*.

1.
 - a. What can you say of the shape of the leaf?
 - b. What is the shape of the apex?
 - c. Of the base?
 - d. Describe the margin.
 - e. Is there a petiole?
 - f. Do you find stipules?
2. Into how many divisions is the leaf cut?
3. *Note.* — A leaf in which the main veins spread out like a fan is said to be PALMATELY VEINED.
 - a. Is the geranium leaf palmately veined?
 - b. Is it netted-veined?
 - c. Compare it in these respects with the other leaves studied.
4.
 - a. Is the leaf smooth or hairy?
 - b. Do the two surfaces of the leaf appear to differ in the number of hairs?
5. Smell the leaf. What is its odor?
6. Determine the taste of the leaf. Is its flavor of advantage to the leaf in any way?
7. Tell in what way this leaf seems to be adapted to its functions.

Drawing. — Upper surface ($\times 1$).

THISTLE OR HOLLY.

Materials. — Fresh leaves of either *Carduus* sp. or *Ilex opaca*.

1. *a.* What is the shape of the leaf?
b. What is the form of the apex?
c. What is the form of the base?
d. What can you say of the margin?
2. Describe the venation of the leaf.
3. What is its consistency? Is this of any advantage to the leaf?
4. *a.* Mention all the ways in which the leaf is modified for its protection.
b. Against what dangers is it protected?

Drawing. — Whole leaf ($\times 1$).

ROSE OR CLOVER.

Materials. — Entire leaves of any species of *Rosa* or *Trifolium*.

1. What is the shape of the leaf as a whole?
2. Is there a petiole present?
3. Is there anything attached to the outer end of the petiole?
4. *Note.* — At the base of the petiole are often found small leaf-like bodies called *STIPULES*. In most kinds of leaves the stipules soon fall off.
 - a. Are stipules present in your specimen?
 - b. Do all the leaves bear stipules?
 - c. Describe the stipules in size, shape, color and attachment.
5. *Note.* — A leaf having a blade consisting of one piece is *SIMPLE*; a leaf in which the blade consists of several distinct pieces (*LEAFLETS*) is said to be *COMPOUND*.
 - a. Is the rose leaf simple or compound?
6. *Note.* — If its leaflets are arranged along either side of the stalk, a leaf is *PINNATELY* compound; if its leaflets radiate from the tip of the stalk, a leaf is *PALMATELY* compound.
 - a. How are the leaflets arranged in this leaf?
7.
 - a. How many leaflets are there?
 - b. Is the number the same in every leaf?
8.
 - a. Describe a single leaflet as to outline, base, apex, margin and venation.
 - b. Are the leaflets in each leaf of the same shape and size?

Drawing. — A leaf, upper surface ($\times 1$).

Label. — Petiole, stipules, leaflets.

PEA.

Materials. — Fresh leaves of any species of pea.

1. Would you describe the leaf as simple or as compound? Give full reason for your answer.
 - a. How many leaflets do you find?
 - b. How are they arranged on the midrib? Are they opposite or alternate?
 - c. What kind of venation would there have been had the leaf been simple?
2. *Note.* — A TENDRIL is an organ of the plant adapted for climbing.
 - a. Describe the tendrils of the pea in form and location.
 - b. By what means does the tendril hold fast?
 - c. To what part of a typical leaf does the tendril correspond?
3.
 - a. How has the leaf of the pea become adapted to its mode of life?
 - b. Of what use would such a leaf be to the plant?

Drawing. — An entire leaf ($\times \frac{1}{2}$).

Label. — Petiole, leaflets, veins, tendrils.

PITCHER PLANT.

Materials. — Plants of *Sarracenia purpurea* in pots.

1. What can you say of the general shape of the leaf?
2. Could you make a flat leaf out of the pitcher? How?
3. *a.* Is the leaf smooth or hairy?
b. Describe the surface of the interior of the pitcher?
4. *a.* Of what use would the cup-like part of the leaf be to the plant?
b. Of what use would the hairs be?
c. What do you find in the pitcher?
d. Explain how insects might be attracted to the plant and become imprisoned.
e. What is the possible use of the dead insects to the plant?

Drawing. — A leaf from the side ($\times 1$).

STOMATA.

(Exercise with the Microscope.)

Materials.—Compound microscopes; slides showing epidermis stripped from a stonecrop and mounted in dilute glycerine.

1. What is the general form of the openings or STOMATA as seen from above?
2. What can you say of the number of stomata?
3. *Note.*—The two large bodies on either side of a stoma are called GUARD CELLS. By changes in the shape of these cells the opening is made larger or smaller.
 - a. How many guard cells do you see?
 - b. Describe the shape of the guard cells about an open stoma.
 - c. Describe any guard cells that show a different appearance from that described in b.

Drawing.—A single stoma showing the guard cells and the adjacent epidermal cells.

ARRANGEMENT OF LEAVES ON THE STEM.

Materials. — Moderately large branches of a Maple.
(This study may profitably be made during an excursion.)

1. Do the leaves show an opposite or an alternate arrangement?
2. Hold the branch so that the light falls on the upper surface of the leaves.
 - a. Count how many leaves get full sunlight.
 - b. Count how many are shaded by their neighbors.
3. a. Note all the adaptations by which the branch brings as many leaves as possible into the light. Are all the petioles of equal length? Do the largest leaf-blades occur near the free end of the branch or far from it?
 - b. Does the arrangement found in the branch hold good throughout the tree?

Drawing. — The branch from above, showing the arrangement of the leaves ($\times \frac{1}{5}$).

FLOWERS.

WAKE-ROBIN.

(*Spring.*)

Materials. — Entire plants of *Trillium grandiflorum* in flower.

1. *a.* Describe the rootstock of the plant in size, form, consistency and character of surface.
b. Describe the position of the roots.
c. Is the rootstock adapted for food storage?
d. Explain why the wake-robin is able to bloom so early.
2. *a.* Describe a leaf as to shape, base, margin and apex?
b. Is it stalked or sessile?
c. Describe the way in which the leaves are grouped?
3. *Note.* — The flower stalk is called the **PEDUNCLE**; its broad end, bearing the parts of the flower, is called the **RECEPTACLE**.
a. Describe the receptacle in size and position.
4. *Note.* — The outer circle or whorl of parts in the flower is called the **CALYX**, each part being called a **SEPAL**.
a. How many sepals do you find?
b. Describe a single sepal in shape and color?
c. Are they separate or united?
5. *Note.* — The whorl of parts just inside the calyx is called the **COROLLA**, each piece being called a **PETAL**.
a. How many petals are there?
b. Describe one as to shape and color.
c. Are the petals separate or united?

6. *Note.*— Within the two outer whorls (collectively called the PERIANTH) are found the ESSENTIAL or REPRODUCTIVE ORGANS of the flower: the STAMENS and the PISTIL. (The latter is in the center of the flower.)

a. How many stamens do you find?

7. *Note.*— Each stamen consists of a stalk or FILAMENT and a box-like structure, the pollen case or ANTHER.

a. Describe a stamen in size, shape and consistency.

b. Describe POLLEN (dust from the anther) as seen with the naked eye.

8. *Note.*— The pistil consists of a broad base, the OVARY, containing the unripe seeds, and a stalk or STYLE. The moist, free end of the style is called the STIGMA.

a. How many stigmas do you find?

b. Do the divisions of the pistil agree with the other floral parts in number?

9. Are the parts of the flower opposite to or alternate with each other? (Look at the flower from above.)

10. *Note.*— When the ovary lies above the line of attachment of the other floral parts to the receptacle, the ovary is said to be SUPERIOR; when below, it is INFERIOR.

a. Is the ovary superior or inferior?

11. *Note.*— A flower is COMPLETE when it has sepals, petals, stamens and pistil.

a. Is the flower of the wake-robin complete or incomplete?

12. *Note.*— A flower is REGULAR when the parts of each whorl are alike in size and shape (e. g., all petals alike).

a. Is the flower of the wake-robin regular or irregular?

13. *Note.* — A flower is SYMMETRICAL when it has the same number of parts, or a multiple of that number, in every whorl.

a. Is the wake-robin symmetrical or asymmetrical?

Drawings. — I. The whole plant ($\times \frac{1}{2}$).

II. Diagram of the flower from the side ($\times 2$).

III. Floral diagram from above ($\times 2$).

Label. — Peduncle, sepal, petal, stamen, pistil.

BUTTERCUP.

(Autumn.)

Materials. — Flowering plants of *Ranunculus acris*.
(With slight modification the questions would serve
for *Oxalis stricta*.) Lenses.

1. *a.* Do the flowers occur singly or in clusters?
b. Are the flowers terminal (at the end of the stem)
or lateral (on the side)?
c. Are the flowers drooping (hanging down) or erect
(upright)?
2. Describe the flower stalk or PEDUNCLE in length, color
and surface character.
3. *Note.* — The outer whorl or circle of leaflike parts (SEPALS)
is called the CALYX.
 - a.* How many sepals are there?
 - b.* Are they separate or united?
 - c.* Describe a sepal in size, shape and color.
 - d.* Are all the sepals alike in shape?
4. *Note.* — The whorl of parts just inside the calyx is the
COROLLA, each part being a PETAL.
 - a.* How many petals do you find?
 - b.* Are they separate or united?
 - c.* Describe a petal in shape, size, color and surface
character.
 - d.* Are the petals all alike in shape?
5. *Note.* — Near their base the petals bear little scales (NEC-
TARIES) which secrete a sweet liquid (NECTAR).
 - a.* How many nectaries are there on a single petal?
 - b.* Are the nectaries on the inner or the outer side of
the petals?
 - c.* What is the use of nectar to a flower?

6. *Note.* — The parts enclosed by the corolla are called the **ESSENTIAL** organs because they give rise directly to the seeds. The essential organs are the **STAMENS** and the **CARPELS** (the latter in the center of the flower).

a. About how many stamens do you find?

7. *Note.* — A typical stamen consists of a box-like pollen case or **ANTHER** supported on a stalk called the **FILAMENT**.

a. Do the stamens in your specimen possess a filament?

b. Describe the color, form and mode of attachment of the anther.

c. Are the stamens all alike in shape?

8. Describe the color and general appearance of **POLLEN**, the material shed by the anthers.

9. *Note.* — The center of the flower is occupied by the **CARPELS** in which lie the unripe seeds or **OVULES**. Each carpel may be considered as a modified leaf.

a. About how many carpels do you find?

b. Are they separate, or united into a single organ (the **PISTIL**)?

c. (Use a lens.) Describe the color, size and outline of a carpel.

d. Are the carpels all alike in size and shape?

10. *Note.* — The tip of a carpel, fitted to catch and hold pollen, is called the **STIGMA**. The lower part of the carpel containing the ovule or ovules is the **OVARY**. The stigma in some plants is elevated on a rodlike structure, the **STYLE**.

a. Is there a style present in your specimen?

11. *Note.* — A flower which possesses sepals and petals in addition to the essential organs is **COMPLETE**.

a. Is your specimen complete or incomplete?

12. *Note*.—A flower which has the same number of parts (or some multiple of that number) in every whorl is **SYMMETRICAL**.

a. Is your specimen symmetrical or asymmetrical?

13. *Note*.—A flower which has the parts in each whorl alike in size and shape is **REGULAR**.

a. Is your specimen regular or irregular?

14. Of what use to the buttercup is its color?

15. *a*. Bite the peduncle and describe the resulting taste.

b. Of what use to the plant is its peculiar flavor?

Drawings.—I. A flower from above ($\times 3$).

II. A view from the side ($\times 3$).

III. A single sepal, petal, stamen and carpel (or pistil) ($\times 3$).

Label.—Sepal, petal, stamen, carpel (or pistil) and peduncle.

SWEET PEA.

Materials. — A few entire plants of *Lathyrus odoratus*, cut flowers.

1. *Note.* — The Sweet Pea belongs to the great Pulse family, the flowers of which give rise to a podlike fruit, as in the bean.
2. Do the flowers occur singly or in clusters?
3. *a.* How many sepals do you find?
b. Are they separate or united?
c. Are they all alike in size and shape?
4. *a.* How many petals are there?
b. Does any one appear to be formed of two united petals?
5. *Note.* — The large petal at the top of the flower is the BANNER, the two side petals are the WINGS and the curved petal lying below is the KEEL.
a. Compare the various petals in size, shape and color.
b. Describe the banner more carefully.
c. Describe a wing.
d. Describe the keel.
Direction. — Gently press down the keel.
6. *a.* What structure rises into view?
b. Describe the pistil (stigma, style and ovary) in size and shape.
7. *a.* Describe the stamens in number, size and shape.
b. Are they attached to the receptacle?
c. What is the shape of the anther and how is it attached to the filament?
8. *Note.* — When petals or stamens are borne on the receptacle they are *HYPOGYNOUS*; when they are attached to the top of the ovary they are *EPIGYNOUS*; when they are attached in a belt around the ovary they are *PERIGYNOUS*.

- a.* Describe the position of the stamens in the sweet pea.
9. *a.* If a bee should alight on the flower in search of honey, what part would the insect rest upon?
- b.* As the weight of the bee bore down the keel, what floral structures would touch the lower surface of the insect's body?
- c.* Of what use to the flower is the arrangement described in (*b*)?
- d.* Of what use to the flower are its color and odor?
10. *a.* Is the flower complete?
- b.* Is the flower regular?
- c.* Is the flower symmetrical?

Drawings. — I. Entire flower from the side ($\times 2$)
II. Entire flower from the front ($\times 2$).
III. Banner, wing and keel, each drawn separately ($\times 4$).

MOUNTAIN LAUREL.

Materials. — Sprays of *Kalmia latifolia*.

1. *a.* How many sepals do you find in the calyx?
b. Are they separate or united?
c. Describe their shape and color.
2. *a.* What is the general shape of the corolla?
b. How many petals are there?
c. Are they united or separate?
d. Describe their shape and color.
3. *a.* How many stamens do you find?
b. Compare the number of stamens with the number of little pockets in the corolla.
c. Are the stamens all alike in size, shape and position?
d. Where does the anther normally lie?
4. *a.* Describe the pistil.
b. Is the ovary superior or inferior?
5. *a.* What part would a bee first touch on entering a flower?
b. What would happen when a bee touched a stamen?
(Touch one with a pencil.)
c. What is the purpose of the device just seen?
6. *a.* Is the flower regular?
b. Is it complete?
c. Is it symmetrical?

Drawings. — I. Side view ($\times 4$).

II. View from above, showing some stamens in place and some sprung out ($\times 4$).

III. A floral diagram ($\times 2$).

IV. A flower cluster from the side ($\times \frac{1}{2}$).

WHITE DAISY OR ASTER.

Materials. — Fresh specimens of *Chrysanthemum leucanthemum* or *Aster* sp. Lenses.

1. *Note.* — The so-called 'flower' of the daisy consists of a HEAD of many small flowers; those of the outer circle are the RAY FLOWERS and those in the center the DISK FLOWERS.

a. Describe the head in general appearance.

2. *Note.* — The whorl of leaflike scales (BRACTS) below the flower cluster is called an INVOLUCRE.

a. Describe the color and general appearance of the involucre.

3. a. Describe one of the ray flowers with reference to size, shape and color.

b. Do these flowers seem to be perfect and complete?

4. a. Describe a disk flower in size, shape and color.

b. Which disk flowers open earlier, those in the center or those at the edge of the disk?

5. *Note.* — Plants like the daisy and sunflower belong to the great COMPOSITE family.

a. What sort of flowers and of flower clusters do you find in the composite family? (Give a brief general description as a summary of your work.)

Drawings. — I. Entire head from above ($\times 2$).

II. Single ray flower ($\times 5$).

III. Single disk flower ($\times 5$).

IV. Longitudinal section of a head ($\times 2$).

FRUITS.

MILKWEED.

Materials. — Dry pods of *Asclepias* sp. empty of seeds.

Vials containing each a single seed; a few full pods for demonstration.

1. *Note.* — A FRUIT consists of a ripened ovary with the adjacent parts and contains the ripe SEEDS. Such fruits as split to permit escape of seeds are DEHISCENT; such as do not do so are INDEHISCENT.

a. Is the milkweed fruit dehiscent or indehiscent?

2. Has the milkweed a dry or a fleshy fruit?

3. *Note.* — The thickened and developed wall of the ovary is called the PERICARP (lit., 'around the fruit'). A dry dehiscent pericarp is called a POD and the parts into which it splits are called VALVES.

a. What kind of fruit does the milkweed produce?

b. How many valves are there?

4. *a.* What peculiar structures do you find attached to the seeds? Describe a seed in detail.

b. Of what use to the seed is the structure just described?

5. Tell why it is desirable that the seeds be scattered far from the parent plant.

6. *a.* What can you say of the number of seeds in a single pod?

b. How do you explain the fact that milkweed is so common?

Drawings. — I. Entire pod from the side, showing the method of dehiscence ($\times 1$).

II. A single seed ($\times 2$).

MAPLE.

Materials. — Keys of *Acer* sp.

1. Is the maple fruit dehiscent or indehiscent? Give reasons for your answer.
2. Is the maple a dry or a pulpy fruit?
3. *Note.* — A dry, indehiscent pericarp provided with wings is called a KEY FRUIT or SAMARA.
 - a. What sort of a fruit is that of the maple? Give reasons for your answer.
 - b. How many seeds does it contain?
4.
 - a. Describe the WINGS in texture, shape and size.
 - b. Of what use to the seed are the structures just described?
5. Tell why it is especially desirable that seed of trees should be scattered far from the parent plant.
6. Name all the devices by which the seed is protected.

Drawing. — Entire fruit ($\times 2$).

CLOT-BUR.

Materials.—Dry burs of *Xanthium spinosum*.

1. *Note.*—In certain plants, the involucre enfolds the old flower head, forming a common covering for the several fruits.
 - a. Does the outside of the bur show signs of a seam?
Does the bur appear to split open to permit escape of the fruits?
 - b. Describe the color, general shape, odor and consistency of the bur.
2.
 - a. Describe any peculiar structures observed on the bur.
 - b. What is the use to the bur of the structures just described?
3. Is the clot-bur likely to be destroyed by seed-eating animals?
4. Describe fully the ways in which burs may be dispersed.
5. (Study the cut surface in a specimen cut across.)
 - a. How many fruits do you find?
 - b. Has each fruit a separate covering?
6. How do you suppose the germinating seeds escape from the bur?

Drawings.—I. Entire bur ($\times 5$).

II. Cut surface ($\times 5$).

OAK.

Materials. — Acorns of *Quercus* sp.

1. *Note.* — The acorn separates naturally into two parts, the **ACORN PROPER** and the **CUPULE**.
2. Describe the cupule in size, shape, color, consistency and surface character.
3. Describe the acorn proper, with regard to size, shape, color and character of surface.
4. *a.* What structure was formerly attached to the apex of the acorn?
b. Does any trace of it still remain?
5. How many seeds are contained in the acorn?
6. *a.* Is the acorn a fleshy or a dry fruit?
b. Is it dehiscent or indehiscent?
7. Where does the acorn obtain the material to produce so great a bulk as appears in an old oak tree?

Drawing. — Entire fruit, acorn and cupule attached
($\times 2$).

JIMPSON WEED.

Materials. — Dry capsules of *Datura* sp.

1. *a.* Is the fruit of Jimpson Weed dehiscent or indehiscent?
b. Is the fruit moist or dry?
2. By how many valves does the fruit open?
3. *a.* What can you say of the number of seeds in a single fruit?
b. Describe the size, shape, color and consistency of the seeds.
c. Do the seeds exhibit any special means of dispersal?
4. *a.* In what several ways are the fruits protected from the attacks of animals?
b. What is the advantage to the seed of the poison it contains?
5. How do you account for the fact that Jimpson Weed is so widely distributed?

Drawing. — A single capsule from the side showing seeds in place ($\times 2$).

PINE CONE.

Materials. — Dry cones of *Pinus resinosa*.

1. Describe the outline of the pine cone as seen from the side.
2. *a.* Describe the arrangement of the scales in the ripe cone.
b. What is the advantage of this arrangement?
3. *a.* Where are the seeds placed? (Pull back a scale.)
b. How many seeds do you find under each scale?
c. Are the seeds enclosed in a seed-vessel or ovary?
d. Compare the seeds in the pine with those of the bean as to position in the fruit.
4. *a.* Describe the seed of the pine as to shape, size, color and consistency.
b. Do you find any peculiar appendage on the seed?
c. What is the purpose of this appendage?

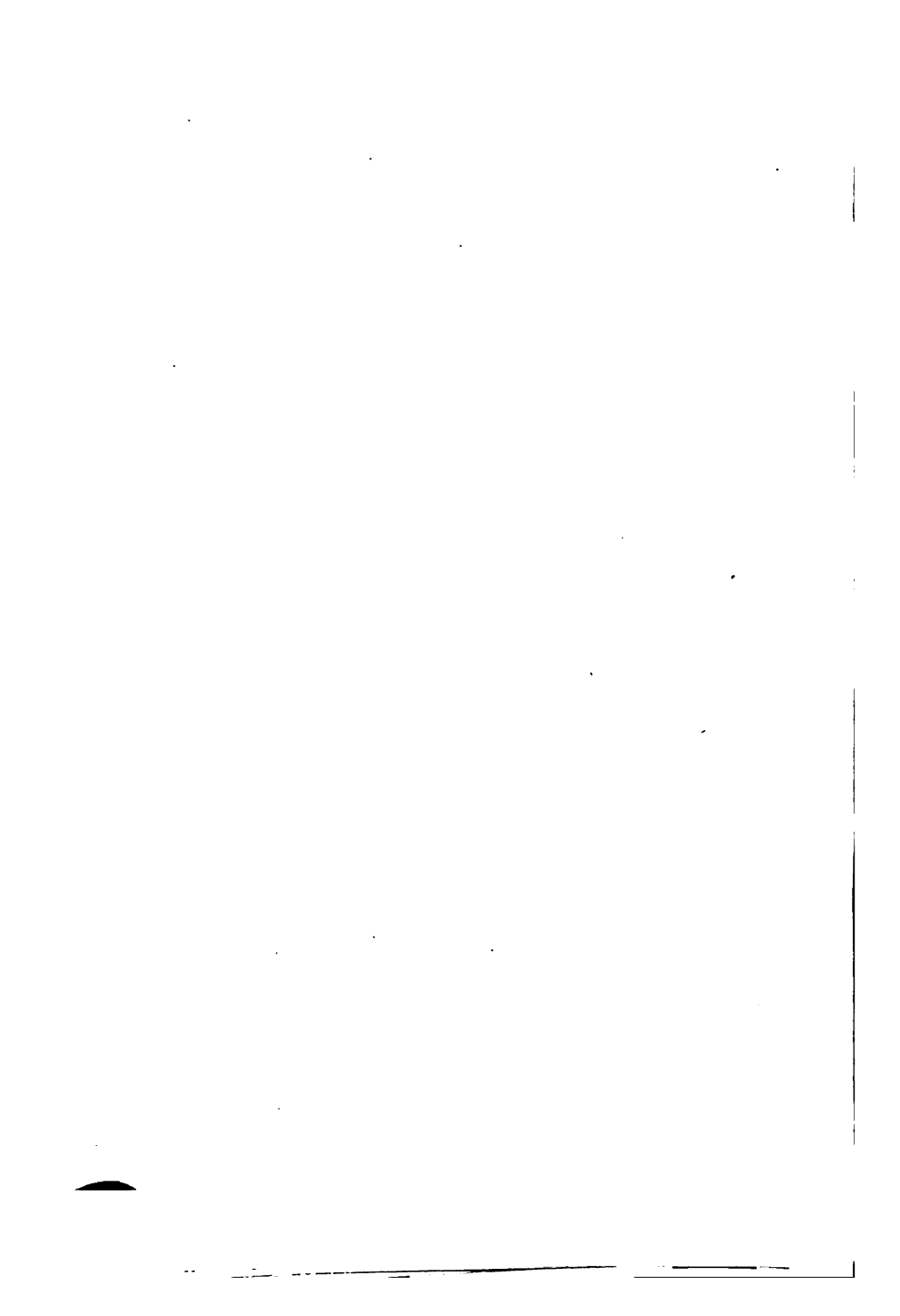
Drawings. — I. Entire cone from the side, showing position of seeds ($\times 1$).

II. A single seed showing 'wing' ($\times 2$).

BOTANICAL STUDIES

CRYPTOGAMS

(Flowerless Plants)



GREEN SLIME.

Materials. — *Pleurococcus* sp., on bark, slides of *Pleurococcus* prepared for the microscope with zinc chlor-iodide.

ON BARK CONTAINING GREEN SLIME.

1. What can you say of the color and general appearance of the plants?
2. Are they found in equal abundance on all parts of the bark?
3. Are they dry or moist?

UNDER THE COMPOUND MICROSCOPE.

(*Low Power.*)

4. a. What is the form of the little bodies or CELLS?
- b. What is their color?
- c. Are they all of the same size?

UNDER HIGH POWER.

(*Specimens prepared with Zincchlor-iodide Solution.*)

5. **Note.** — A plant CELL consists of a mass of PROTOPLASM (living matter), surrounded generally by a wall of CELLULOSE.
 - a. Describe the CELL WALL in color, thickness and outline.
 - b. Do you find green coloring matter (CHLOROPHYLL)?
 - c. Could Green Slime form starch? Give reasons.
6. Can you find a NUCLEUS (a small ovoid body) in the cell?
7. a. Are all the cells entirely separate from each other?

b. What evidence have you that the cells divide in order to increase in number?

c. Do any of the cells seem to have formed colonies?

Drawings. — I. A single cell.

II. A two-celled colony.

III. A three-celled colony. (Due to the more rapid division of some cells.)

IV. A four-celled colony.

POND SCUM.

Materials. — *Spirogyra* sp. in small glass dishes of fresh water; prepared slides of fruiting material.

GROSS STRUCTURE.

1. *a.* What is the general form of a mass of plants?
- b.* What is the color?
- c.* Where would such plants live?
- d.* Does the plant seem to have organs for attaching itself?
- e.* How does it 'feel' when rubbed between the fingers?

UNDER THE LOW POWER OF THE COMPOUND MICROSCOPE.

2. *Note.* — A thread-like plant body is called a FILAMENT.
 - a.* What can you say of the length of the filaments?
 - b.* Do they seem to branch?
 - c.* Are they all of the same diameter?
3. *a.* What can you say of the number of little structures (CELLS) making up the whole filament?
- b.* How are the cells placed with reference to each other?
- c.* Is there any green coloring matter (chlorophyll) present?

Direction. — With the high power of the microscope focus carefully on one cell, using the fine adjustment to bring upper and lower surfaces of the cell in turn into focus.

4. *a.* What is the shape of a single cell?
- b.* Describe the shape of the partitions separating the cells.

5. a. Describe the chlorophyll mass in form and character of margin. Is it uniformly distributed throughout the cell?
- b. Is there more than one chlorophyll band in a cell?
- c. How many complete turns does such a band make in a cell?
- d. Compare the distribution of chlorophyll in Green Slime and Pond Scum.

IN PREPARED SPECIMENS OF THE PLANT IN FRUIT.

6. *Note.* — When two cells in adjoining filaments put out tubes by means of which the contents of one cell mix with the contents of the other, the cells are said to be in CONJUGATION.
 - a. Describe the appearance of a conjugating filament?
 - b. Do you find any cells where the contents are passing over?
7. *Note.* — The cell formed as a result of conjugation is called a ZYGOSPORE.
 - a. Describe a zygospore as to size, shape, and thickness of coat?
 - b. Of what use would zygospores be to a plant like Pond Scum?
 - c. Do the bodies of water in which Pond Scum lives ever dry up?

Drawings. — I. The whole plant in a dish showing habit of growth ($\times 1$).

II. A single filament under the low power.

Label. — Cells, cell walls, chlorophyll bodies.

III. A single cell (high power).

Label. — Chlorophyll bands, cell wall, cell body.

IV. A conjugating filament.

Label. — Conjugating tubes, zygospores, cell walls.

ROCKWEED.

Materials. — Fresh or formol specimens of *Fucus* sp. in fruit. Specimen soaked in alcohol 95 per cent in order to show the chlorophyll.

1. *a.* What is the general shape of the body?
b. Is the body simple or branched?
2. *Note.* — A generally leaflike plant body, not divided into root, stem and leaf, is called a THALLUS.
 - a.* Is Rockweed a thallus?
 - b.* Is Rockweed attached to anything when alive, or does it float freely?
 - b.* Can you find any part of the plant modified for a 'holdfast'?
4. *a.* Is part of the plant modified to enable it to float?
b. Describe two kinds of bladders as to position, consistency, color and surface character.
5. *Note.* — The bladders at the free ends of the thallus contain little pits (the 'fruiting bodies'), which when ripe are filled with SPORES.
 - a.* Describe the fruiting bodies in number and position.
6. *a.* Does Rockweed contain chlorophyll? (Note the color carefully.)
 - b.* What kind of food would it use?
7. *a.* Would Rockweed easily become water soaked?
b. Would the plant be likely to be eaten by fishes?
c. Would it be easily torn by the waves?
8. Mention all the ways in which Rockweed is adapted to its peculiar mode of life.

Drawing. — Part of the plant ($\times 2$).

Label. — Thallus, bladders, fruiting bodies, holdfast (if you find it).

YEAST.

Materials. — Sediment of Commercial yeast; iodine solution; compound microscopes.

EXAMINATION WITH THE MICROSCOPE.

1. *a.* What is the color of the mass of yeast plants as seen with the low power?
- b.* What form do the plants seem to have?

WITH HIGH POWER.

2. *a.* Are all the cells of the same size?
- b.* Have they all the same shape?
- c.* Do you find any cells joined together?
- d.* How do you account for this?
- e.* Are the cells which are budded off of the same size as those from which they have come?

Direction. — Run some iodine solution under the cover glass. Examine carefully a single cell.

3. *a.* What is the color of the cell?
- b.* What substance does it contain?
- c.* Do you find a clear spot or VACUOLE in any of the cells?
- d.* What is the appearance of the contents of a cell?

Drawings. — I. A single cell.

II. A cell showing buds.

BLACK MOULD.

Materials.—*Rhizopus nigricans* growing on sweet potato or bread, given out in small glass dishes; fruiting specimens mounted in dilute alcohol; compound microscopes.

1. *a.* What is the general appearance of the mould?
b. Does it grow uniformly on all parts of the bread or potato?
2. *a.* Does the mould contain chlorophyll?
b. Is it able to make its own food?
c. Where does it get its food supply?
3. *Note.*—A plant or animal which lives at the expense of a LIVING plant or animal is called a PARASITE; a plant or animal obtaining its food from the DEAD bodies of plants or animals is called a SAPROPHYTE.
a. Does the mould grow on living or on dead matter?
b. Is the mould a parasite or a saprophyte?
c. Name all the materials upon which you have found mould growing.
4. *Note.*—The thread-like parts of the mould (called *HYPHÆ*) taken together form a MYCELIUM.
a. Are the hyphæ separate from each other?
b. Do the hyphæ branch?
c. How are they attached to the bread?
5. *Note.*—The tiny bodies rising on little stalks are the SPORE CASES (SPORANGIA).
a. Are all the spore cases of the same size?
b. Are all the spore cases the same in color?
c. How do you account for the differences?
d. Do all the sporangia rise above the general mass of the mould?

Direction. — Study with the low power of the microscope.

6. Do you find partitions (such as we saw in Pond Scum) showing that the hyphæ consist of distinct cells?
7. *a.* What is the shape of an unopened sporangium?
b. How do the sporangia open?
8. *Note.* — The little knob projecting into the sporangium is called the COLUMELLA.
 - a.* How is the columella related to the stalk of the sporangium?
 - b.* How much relative space does it occupy in the sporangium?
9. *a.* Describe the shape, size and color of the SPORES.
b. What can you say of the number of spores in a single sporangium?
c. By what means are the spores scattered?

Drawings. — I. The MYCELIUM in part, showing the fruiting hyphæ and sporangia ($\times 4$).

II. A series of four sporangia showing the stages of development. (Low power.)

III. An opened sporangium showing spores. (Low power.)

MUSHROOM.

Materials. — Fresh specimens of *Agaricus campestris*; spore prints; chart or microscopic preparation showing spores in situ.

1. *Note.* — The plant body consists of two parts: a branching mass of white threads (under ground), the MYCELIUM; and the FRUITING BODY which rises above the surface of the ground.
 - a. Do you find any traces of the mycelium?
 - b. What is the general shape of the fruiting body?
 - c. What can you say of its consistency and color?
 2. Describe the STALK as to diameter, length, color and surface character?
 3.
 - a. What is the general shape of the CAP as seen from above?
 - b. Compare the upper and lower sides of the cap with reference to color and character of surface.
 4. *Note.* — In young specimens, the lower surface of the cap is covered by a thin VEIL.
 - a. Can you find the place in old specimens where the veil was attached to the stalk?
 - b. What is the general shape of the fragment of veil (the RING) still attached to the stalk?
 5. *Note.* — The ridges on the under surface of the cap, called GILLS, bear the developing spores.
 - a. Describe the arrangement of the gills with reference to the stalk.
 - b. What can you say of the size and number of spores as seen with the naked eye? (Use a spore print.)
- Direction.* — Use a microscopic slide or a chart in answering 6. a. and 6. b.

6. *Note.*—The cells which project from the surface of the gills and which bear the spores are called **BASIDIA** (sing. *basidium*).

- a. Describe the position of the spores on a basidium.
- b. How many spores are found on each basidium?

GENERAL QUESTIONS.

7. a. What is the advantage of the long stalk to the mushroom?
b. Why are the spores found on the lower instead of the upper side of the cap?
8. a. Do mushrooms contain chlorophyll?
b. Could they manufacture starchy food?
c. Where and how must they get their food?

Drawings. — I. Side view of the fruiting body ($\times 1$).

II. View of the under side of the cap ($\times 1$).

Label. — Stalk, cap, gills, ring.

III. A single basidium and spores (drawing two inches in length).

BRACKET FUNGUS.

Materials.— Entire specimens of *Fomes megaloma*; prepared slides or charts; a few specimens of *Hydnum* sp. and *Dædalia* sp.

1. *Note.*— The fruiting body of the bracket fungus is usually found projecting from dead or dying wood, which is penetrated by the mycelium.
 - a. What is the general shape of the fruiting body?
 - b. In what position would it be found growing on a tree trunk?
2. Compare the upper with the lower side in consistency, color and character of surface.
3.
 - a. Describe the arrangement, number and size of the spore-bearing tubes.
 - b. On which side are they found, and why?
 - c. Describe the appearance of the spore-bearing surface in other specimens shown to you.

FROM MICROSCOPIC SLIDE OR CHART.

4. *Note.*— The long, spore-bearing cells projecting into the tubes are called **BASIDIA** (sing. basidium).
 - a. Describe the form and structure of a basidium as seen in a cross-section of a tube.
 - b. Compare the position of the spores with that observed in the mushroom.
5.
 - a. Compare the fruiting body in the bracket fungus and the mushroom as to general appearance.
 - b. Compare the two in consistency.
 - c. Is any part of the fruiting body found lacking in the bracket fungus that was present in the mushroom?

- d.* Compare the spore-bearing surfaces in the two forms.
- e.* What can you say of the number of spores in each?
Is there any advantage in this?
- f.* How might the spores be scattered?
- 6. *a.* Does either of the plants contain chlorophyll?
b. Where and how do they get their food?

Drawings. — I. View from the side ($\times 1$).

Label. — Upper, lower and attached surfaces, spore tubes.

II. View from below ($\times 1$).

III. View of a cross-section of a tube
(drawing two inches in diameter).

Label. — Basidium, spores, wall of tube.

LICHEN.

Materials. — Dry specimens of any large form: e. g.,
Sticta sp. or Physcia sp. Chart showing the structure
of the apothecia.

1. What is the general shape of the body?
2. Describe the character of the upper and the lower surface. State all the differences you observe.
3. *a.* Is the body all in one piece?
b. Is it a thallus? Give your reasons.
4. *a.* Is the body soft and moist?
b. Where do lichens grow?
5. *Note.* — The lichen is a partnership between cells of an ALGA and a FUNGUS. The fungus part reproduces (somewhat in the manner of Black Mould) by spores and the alga (as does Green Slime) by cell division.
 - a.* Which part gives the greenish color to the lichen?
 - b.* What kind of food does an alga make and use?
 - c.* What kind of food does a fungus need?
6. *Note.* — The dark cuplike structures sometimes found on the lichen are the fruiting bodies which contain the spores.
 - a.* Describe a fruiting body in size, color, shape and position.
 - b.* To which part of the lichen does the fruiting body belong, alga or fungus? (See the chart.)
7. State fully all the advantages resulting to the alga and the fungus respectively, when they live together in partnership as a LICHEN.

Drawings. — I. Entire lichen as seen from the upper surface ($\times 1$).

II. View of a microscopic section through a fruiting body (drawing four inches long).

Label. — Fungus hyphæ, cells of the alga.

PIGEON WHEAT MOSS.

Materials. — Fresh specimens of sterile plants of *Polytrichum vulgare*; fresh or preserved fruiting plants; models, charts or prepared slides of protonema, antheridia and archegonia.

STERILE SHOOT.

1. Do you find parts that resemble root, stem and leaves?
2. Is the stem branched?
3. *a.* In what way are the leaves arranged?
b. Describe the shape of a leaf.
4. *a.* Does the moss contain chlorophyll?
b. How do you know?
5. *a.* What kind of food does the moss use?
b. How do you know?

FRUITING BODY.

6. *Note.* — The spores are contained in a case or CAPSULE which is borne on a long stalk.
 - a.* Compare the length of the fruiting body (stalk and capsule) with that of the leafy moss plant.
 - b.* Describe the capsule in shape, color and position.
 - c.* Do you find a little cap or hood over the capsule? If so, describe it.

FROM CHART, MODEL OR PREPARED SLIDES.

7. *Note.* — A spore, when sown in a favorable place, will give rise to a tiny, thread-like plant, called the PROTONEMA.
 - a.* Describe the protonema in shape and color.
 - b.* How does it grow?

8. *Note.*—The protonema gives rise, by budding, to leafy moss plants which may contain either male or female organs.

a. Where are the male and the female organs respectively located?

b. Are they both situated on the same plant body?

9. *Note.*—The male organ is filled with motile cells, the ANTHEROZOIDS, while the female organ contains a single non-motile EGG CELL.

a. Describe the male organ more fully.

b. Describe the female organ more completely.

10. *Note.*—After FERTILIZATION, or the union of an antherozoid with an egg cell, the egg gives rise by continued division to the stalk and the capsule in which the spores are produced.

a. By what means does an antherozoid reach the egg cell?

11. a. Trace the entire history of the moss plant beginning with the fertilization of the egg cell.

b. Does the plant which bears the sex organs give rise directly to a form like itself?

c. Does the spore-bearing part give rise directly to a body like itself?

12. *Note.*—The alternation, in the history of a plant, of a body which bears sex organs with a body which reproduces only by spores, is called ALTERNATION OF GENERATIONS.

Drawings.—I. The leafy moss plant ($\times 1$), from specimen.

II. Male organ with antherozoids (drawing two inches long), from chart or slide.

BOTANICAL STUDIES.

- III. Female organ with egg cell (drawing two inches long), from chart or slide.
- IV. Spore-bearing plant ($\times 1$), from specimen.
- V. Protonema (drawing two inches long), from chart or slide.

ROCK FERN.

Materials. — Entire plant of *Polypodium vulgare* showing the underground stem; fresh fronds in fruit; compound microscopes, slides and cover glasses; charts.

1. *a.* Describe the underground stem or Rootstock with reference to color, diameter, surface character and consistency.
b. Would such a stem lie far underground?
2. Describe any root-like organs you may find, as to shape, size and position on the rootstock.
3. *a.* From what part of the rootstock do the green leaves or FRONDS arise?
b. Have fronds arisen from this same rootstock in previous years? Give reasons.
c. Describe a young frond or CROZIER.
4. *Note.* — The main axis of the frond is called the RACHIS; the leaflets on either side are the PINNÆ (sing. pinna).
a. How are the pinnæ arranged on the rachis?
b. Do you find a midrib in each pinna?
5. *Note.* — On the lower side of the pinnæ are the SORI (sing. sorus) or groups of spore cases.
a. Describe the sori in arrangement and number?
b. How are they arranged with reference to the veins of the pinnæ?
c. Describe a single sorus as to shape, size and color.

WITH THE LOW POWER OF THE MICROSCOPE.

6. *Note.* — The sorus is composed of many small spore cases or SPORANGIA, which in some ferns are covered by an outgrowth from the leaf called the INDUSIUM.

- a. Is there an indusium present?
- b. What is the arrangement of the sporangia in the sorus?

STUDY A SINGLE SPORANGIUM WITH THE HIGH POWER.

- 7. a. Has the sporangium a stalk?
- b. What is the shape of an unbroken sporangium?
- 8. *Note.*—The thick ring of cells on one side of a sporangium is called the ANNULUS.
 - a. Study an open sporangium. Which has been torn, the annulus or the other tissues? Why is this so?
- 9. *Note.*—The reproductive bodies contained in the sporangium are called SPORES.
 - a. Describe a spore in shape, color and character of surface.
 - b. Are the spores few or numerous? Why is this so?

THE FOLLOWING QUESTIONS MAY BE ANSWERED FROM
BLACKBOARD DRAWINGS OR CHART:

- 10. *Note.*—When a spore germinates, it gives rise to a small thallus-like plant which bears both male and female organs and which is therefore the SEXUAL STAGE of the fern.
 - a. What is the general shape of the PROTHALLUS or sexual fern plant?
 - b. Are any root-like organs present?
- 11. *Note.*—The male organs are spherical in shape while the female organs are somewhat flask-shaped.
 - a. Describe the position of the male and the female organs respectively.
 - b. How do these organs compare in form and position with the corresponding organs in the moss?

12. Do the ferns illustrate the process of alternation of generations? Explain fully.
13. Trace the entire history of a fern, beginning with the the germination of a spore.

Drawings. — I. A fern plant ($\times \frac{1}{2}$).

Label. — Rootstock, roots, fronds, croziers, pinnæ, rachis.

II. A pinna showing sori ($\times 2$).

III. A sporangium.

Label. — Stalk, annulus, spores. (High power.)

IV. Prothallus (drawing two inches in length).

Label. — Male and female organs and roots.

FIELD HORSETAIL.

Materials.—Sterile and fruiting specimens of *Equisetum arvense*.

STERILE SHOOT.

1. *a.* Describe the general appearance of the sterile shoot.
b. How many nodes and internodes do you find in your specimen?
2. *a.* Describe the leaves in shape, size and color.
b. How are the leaves arranged on the stem?
c. Do they contain chlorophyll?
3. *a.* Describe the character of the stem as to shape, toughness and surface.
4. *a.* Describe the arrangement of the branches on the stem.
b. Do the branches contain chlorophyll?
c. Are they jointed or unjointed?
5. Is the stem solid or hollow? Is this condition an advantage to the plant?
6. *a.* Rub your finger nail over the stem as it is held near your ear. Describe the sound that results.
b. To what is the sound due?
c. Why is the plant called the 'scouring rush'?

FERTILE SHOOT.

7. *Note.*—The Sporangia are found at the tip of the shoot.
a. How are the sporangia arranged on the stem?
b. What is the appearance of a single sporangium?
8. *Note.*—The spores are found on the under surface of the sporangium.

- a. What advantage do the spores gain from their position?

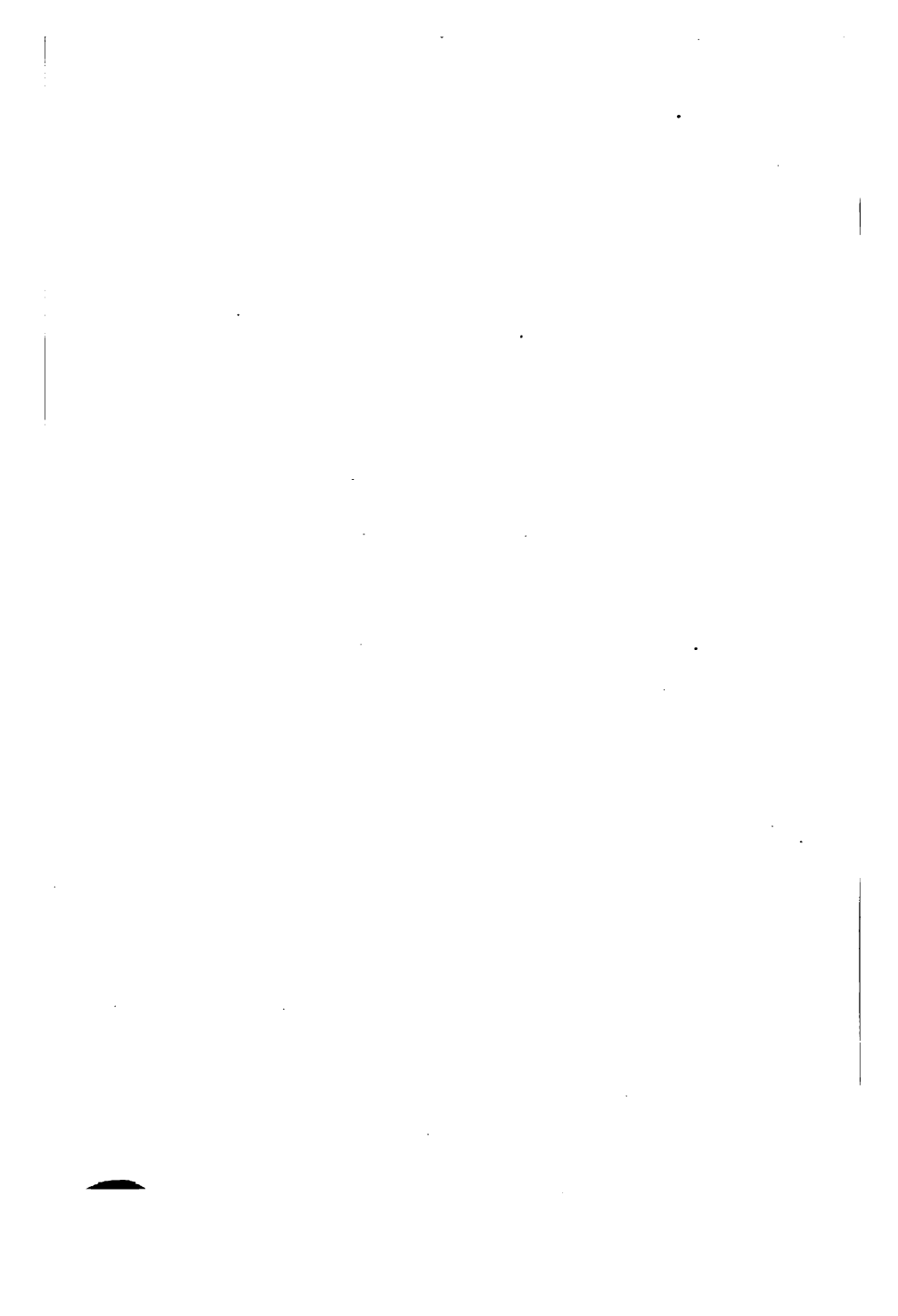
Drawings. — I. Entire sterile plant ($\times \frac{1}{2}$).

II. Tip of the fertile shoot showing sporangia ($\times 4$).



PART II

ZOÖLOGICAL STUDIES



ARTHROPODA.

GRASSHOPPER.

ANATOMY.

Materials. — Specimens of *Melanoplus femur-rubrum*, preserved in 5 per cent formol, or in 80 per cent alcohol; living grasshoppers in covered glass dishes or in glass vials stoppered with perforated corks.

1. Into how many REGIONS is the body divided?
2. *Note.* — The ANTERIOR or front part is the HEAD, the middle piece is the THORAX and the POSTERIOR or hind part is the ABDOMEN.
3. What fraction of the whole body is taken up by the head, the thorax and the abdomen, respectively?
4. *Note.* — The ringlike parts lying one behind the other are called SEGMENTS.
 - a. How many segments can you count in the abdomen?
 - b. Are the segments all alike in size and shape? Mention any exceptions.
5. *Note.* — Just above the ridge running lengthwise on either side of the abdomen, are the SPIRACLES or breathing holes.
 - a. How many spiracles are there in a segment?
 - b. How many segments bear spiracles?
6. *Note.* — Underneath the wings, on the first segment of the abdomen, is a thin oval plate, the TYMPANUM or eardrum.

- a. How many tympana can you find?
7. *Note.*—The male grasshopper has a rounded, upturned abdomen; the female has the abdomen terminating in sharp prongs called collectively the OVIPOSITOR ('egg-layer').
- a. How many parts are there in the ovipositor?
8. How many segments are there in the thorax?
9. Are any of the segments movable? If any, state which.
10. *Note.*—An APPENDAGE is a movable structure attached or appended to the body: as legs and feelers.
- a. How many appendages are there on the thorax?
- b. Do the appendages occur singly or in pairs.
11. Are the legs equal in length and in thickness? Which legs are the longest and which the shortest?
12. How many separate parts do you find in the hind leg?
13. *Note.*—The largest parts in the leg are the following: the FEMUR, the big piece near the body, the TIBIA, the slender piece next following, and finally the TARSUS or foot.
- a. Is the tarsus all in one piece?
- b. What structures do you find on the end of the tarsus?
14. What is the position of the wings when at rest?
15. Does either pair fold up like a fan? If so, which pair?
16. Describe the differences between the fore and the hind wings in size, color and thickness.
17. What is the shape of the head as seen from the side and as seen from the front?
18. Is the head movable?
19. How many pairs of large eyes are there?

20. *Note.*—The large eyes are said to be COMPOUND because they are made up of many small eyes.
21. Describe the number and position of the SIMPLE eyes (OCELLI). (Look on the front of the head.)
22. Describe, with reference to the compound eyes, the location of the ANTENNÆ or long feelers.
- a. How many antennæ are there?
23. *Note.*—The MANDIBLES or upper jaws are covered by a movable flab, the LABRUM or upper lip.
- a. Describe the mandibles in color and shape.
- b. How do they compare with your own jaws as to direction of movement?
24. How many pairs of PALPS or short feelers can you find?
25. *Note.*—One pair of palps extends from the MAXILLÆ or little jaws and the other pair is attached to the LABIUM or lower lip.
26. Where are the hard parts (the SKELETON) of the grasshopper situated?
27. *Note.*—A skeleton on the outside of the body is an EXOSKELETON; one on the inside is called an ENDO-SKELETON.
28. How do the eyes of the grasshopper compare with yours in position in the head?
29. Compare the ratio of size of eye to size of head in the grasshopper and man.
30. Are the grasshopper's eyes movable? How do they compare with your eyes in this respect?
31. In what directions can a grasshopper see? Give your reasons.
32. Do you find distinct right and left sides in the body?
-

33. *Note.*—A body in which the right and left sides are counterparts of each other is said to show **BILATERAL SYMMETRY**.

ACTIVITIES.

34. *a.* Describe briefly the movements of the abdomen.
b. What is the purpose of these movements?
35. *a.* In how many different ways can a grasshopper move from place to place?
b. Which way is most often used?
36. *a.* What is the **FUNCTION** or use of the fore legs?
b. What is the function of the hind legs?
37. Tell how the hind legs are fitted for their special work.
38. (*Direction.*) Cover the lower part of the bottle for a moment with the hand.
a. How does the grasshopper act?
b. Does this prove that the grasshopper can see?
39. If the insect will eat a piece of grass, answer the following questions:
a. How does the grasshopper hold the blade of grass when eating?
b. Describe the motions of the jaws and palps.

Drawings.—I. Entire animal from the left side ($\times 2$).

Label.—Head, thorax, abdomen, antennæ, palps, compound eye, wings, legs (femur, tibia, tarsus), spiracles and (in the female) ovipositor.

II. Dorsal view of the entire animal, wings outspread ($\times 2$).

III. The separate mouth parts ($\times 10$).

IV. The head from the front ($\times 5$).

BUTTERFLY.

Materials. — Dry specimens of *Pieris rapae* placed in a moist chamber overnight; prepared slide of wing showing scales; compound microscope.

1. Tell how many regions you find in the body of the butterfly, and name them.
2. *Note.* — The back or upper part of the animal is called the DORSAL surface; the belly or lower part is called the VENTRAL surface:
3. To which surface are the wings and the legs, respectively, attached?
4. How many pairs of wings do you find?
5. Compare the fore wings with the hind wings as to size and shape.
6. *Note.* — The thickened ridges on the wings are called VEINS.
7. What purpose do the veins serve?
8. What material do you find covering the wings and the body, respectively?
9. *Note.* — The wings of the butterfly are covered with tiny SCALES.
 - a. Describe the shape and arrangement of the scales. (Demonstration.)
 - b. Are these scales colored; how do you know?
10. How are the wings carried when at rest?
11. Compare the legs of the butterfly with those of the grasshopper in number, size and function.
12. Compare the eyes of the butterfly with those of the grasshopper in size and position.
13. Compare the antennæ of the butterfly with those of the grasshopper in shape and length.

14. *Note.*—The short, fluffy projections on the front of the head and below the eyes are the LABIAL PALPS.
15. What structure do you find between the palps?
16. *Note.*—The coiled tube is the PROBOSCIS.
17. What form of food could the butterfly take with this organ?
18. Compare the method of taking food in the butterfly and the grasshopper.
19. How does the body proper of the butterfly compare with that of the grasshopper?
20. *a.* Are both fore and hind wings used in flying?
b. Compare the butterfly with the grasshopper in this respect.
21. Which could fly the better: butterfly or grasshopper? Give your reasons.
22. Which could leap the better? Give reasons.
23. Which could walk the better? Give reasons.
24. Is the butterfly bilaterally symmetrical?

Drawings.—I. Entire animal from the left side ($\times 1\frac{1}{2}$).

Label.—Head, thorax, abdomen, wings, legs, antennæ, eye, labial palp, proboscis.

II. Side view of head ($\times 5$).

III. View of several scales showing form and arrangement.

CATERPILLAR.

Materials.—Formol specimens of any large species.

1. Describe the surface of the caterpillar.
2. What regions do you see in the body?
3. *a.* Into how many segments is the body divided?
b. Are all the segments alike in size and in shape?
4. *a.* How many pairs of legs do you see?
b. To what segments are the legs attached?
5. *Note.*—The legs near the posterior end of the body are called ABDOMINAL LEGS.
 - a.* Compare the caterpillar with the butterfly as to number and position of the legs.
 - b.* What name would you give to the legs attached just behind the head?
6. *a.* What purpose do the mouth parts serve?
b. What form of food could the caterpillar take best?
7. If the spiracles are visible, tell their number, shape and position.
8. In what ways are the butterfly and the caterpillar alike in structure?
9. In what ways do the caterpillar and the butterfly differ in structure?

Drawing.—Entire animal from the left side ($\times 1$).

Label.—Head, thorax, abdomen, thoracic legs, abdominal legs.

DRAGON-FLY.

Materials. — Dried specimens of any species.

1. *a.* What regions do you find in the body?
b. What fraction of the whole body is occupied by each region?
2. *a.* How many segments do you find in the abdomen?
b. Does the abdomen bear appendages?
c. Compare the thickness of the thorax with that of the abdomen?
3. Compare the legs of the dragon-fly with those of the grasshopper in the following ways:
a. in number;
b. in place of attachment;
c. in size and
d. as to the number of separate parts (e. g., the femur).
4. What structure do you find on the tip of the tarsus? What is its use?
5. Compare the fore wings with the hind wings in size and thickness?
6. What kind of pattern is formed by the wing veins?
7. Compare the distance between the attachments of the fore and the hind wing in the dragon-fly and the grasshopper.
8. Is the head freely movable?
9. Which has the larger head as compared with the body, dragon-fly or grasshopper?
10. Compare the compound eyes with those of the grasshopper in size, shape and position.
11. Describe the antennæ in size and position.

12. Compare the jaws with those of the grasshopper in size, shape and direction of movement.
13. *Note.* — The dragon-fly feeds on other insects.
 - a. How is the body fitted, as to eyes, jaws and wings, for catching prey?
14. Why is the thorax so large and strong?
15. Is the dragon-fly bilaterally symmetrical?

Drawings. — I. Dorsal view of the entire animal
($\times 1$).

Label. — Head, thorax, abdomen, legs, wings (veins), eyes.

II. Views of the separate mouth parts.

BEETLE.

Materials. — Formol specimens of any large form
(e. g., *Hydrophilus* sp.).

1. How does the outer covering of the beetle compare with that of the grasshopper?
2. *a.* Compare the ventral surface with the dorsal surface in color.
b. Can you give a reason for any difference in color between the two surfaces?
3. What regions do you see in the body?
4. What is the outline of the body as seen from above and as seen from the side?
5. How many segments do you find in the abdomen?
6. How does the abdomen compare with that of the grasshopper?
7. Compare the legs with those of the grasshopper:
 - a.* in number;
 - b.* in position and
 - c.* in function.
8. *Note.* — The wings are protected by a pair of tough wing-covers called the ELYTRA.
 - a.* Describe the color and shape of the elytra.
 - b.* Do the elytra overlap each other?
9. Describe the wings, if you can see them.
10. Compare the head with that of the grasshopper in size and shape.
11. Compare the antennæ in beetle and grasshopper as to length, shape and position.
12. What are the mouth parts fitted for?
13. Compare the eyes in beetle and grasshopper as to size and position.

Drawings. — I. Dorsal view of the entire animal ($\times 2$).

Label. — Head, thorax, abdomen, elytra, eyes, antennæ, legs.

II. Ventral view showing regions of the body ($\times 2$).

HOUSE-FLY.

Materials. — Alcoholic specimens of house-fly.

1. *a.* How many regions can you find in the body?
b. Which is the largest region?
 2. To which region are the legs and the wings attached?
 3. Compare the wings of the fly with those of the grasshopper in number and position.
 4. Describe the position of the wings when at rest.
 5. *Note.* — The hind wings are rudimentary (very small). Behind them lies a pair of knobbed hairs, the **BALANCERS**.
 6. *a.* Is the head movable?
b. Is there a neck?
 7. Describe the compound eyes in number, position and color.
 8. *Note.* — The little knobbed stalk on the lower side of the head is called the **PROBOSCIS**.
 - a.* How is the proboscis carried when not in use?
 - b.* How would the fly use the proboscis in eating?
- Drawing.* — Entire animal from the left side ($\times 4$).
- Label.* — Head, thorax, abdomen, eye, wing, legs proboscis.

BUMBLE-BEE.

Materials. — Alcoholic specimens of any species.

1. Compare the covering of the body with that of the grasshopper.
2. Into how many regions is the body divided?
3. What is the shape of the abdomen?
4. *Note.* — Some specimens show, at the tip of the abdomen, a sharp, bristle-like structure, the *STING*.
 - a. Describe the sting more exactly in shape and length.
5. Compare the legs with those of the grasshopper in number and position.
6. *a.* How are the wings carried when at rest?
b. Compare the fore with the hind wing in shape, size and thickness.
7. Compare the fore wings in the bee and grasshopper with regard to length, shape and thickness.
8. What is the outline of the head as seen from the front?
9. Compare the antennæ of the bee with those of the grasshopper in length and shape.
10. Describe the compound eyes in number and position.
11. Describe the ocelli (simple eyes) in number and position.
12. *a.* Describe the general appearance of the mouth parts.
b. For what purpose do they seem to be fitted?

Drawing. — Left lateral view of entire animal ($\times 2$).

Label. — Head, thorax, abdomen, legs, wings, eye, antenna, sting.

TABLE OF COMPARISONS.

(Answer in tabular form the following questions for each of the insects studied.)

1. How many regions in the body?
2. Does the abdomen bear legs?
3. Is there any ovipositor or sting?
4. How many segments are there in the thorax?
5. How many pairs of legs attached to the thorax?
6. What purpose are the legs fitted for?
7. How many pairs of wings?
8. Which pair is the larger?
9. Which pair is the stronger?
10. How are the wings carried when at rest?
11. How many compound eyes?
12. How many ocelli?
13. What is the shape of the antennæ?
14. For what purpose are the mouth parts fitted?
15. *Note.*—The points of structure in which all the preceding forms agree, are the characteristics of the class
INSECTA.
16. Define an insect.

SPIDER.

Materials. — Alcoholic specimens of any large form.

1. How many distinct regions are there in the body?
2. *Note.* — The head and thorax when joined in one piece are called the CEPHALO-THORAX.
 - a. Describe the shape of the cephalo-thorax.
3. Describe the abdomen in size and shape.
 - a. How much space is occupied by the cephalo-thorax and the abdomen, respectively?
4. *Note.* — On the ventral side of the abdomen are short projections, the SPINNERETS.
5. Locate the spinnerets more exactly.
6. *Note.* — On either side of the abdomen are little slits, the openings to the breathing organs or LUNG SACS.
 - a. How many lung sacs are there in your specimen?
7.
 - a. How many pairs of legs are there?
 - b. To which surface of the body are they attached?
 - c. Are the legs all in one piece?
8. *Note.* — The short, leg-like structures in front of the true legs are called the PEDIPALPS.
 - a. How do the pedipalps compare in size and shape with the true legs?
9. *Note.* — Lying in front of the pedipalps is a pair of POISON FANGS.
 - a. Describe the poison fangs in length, shape and position.
10. Describe the simple eyes in position and number.
11. *Note.* — The female spider has generally a larger abdomen than the male.

- a. Is your spider a male or a female?
12. Is the spider bilaterally symmetrical?

Drawings. — I. Dorsal view ($\times 2$).

Label. — Cephalo-thorax, abdomen, legs, pedipalps,
poison fangs, eyes.

II. Ventral view ($\times 2$).

Label. — Lung sacs, spinnerets and the parts seen
in I (except the eyes).

CENTIPEDE.

Materials. — Alcoholic specimens of *Lithobius* sp.

1. Is the animal segmented?
2. What kind of a skeleton do you find?
3. What can you say as to the symmetry of the body?
4. What is the general form of the animal?
5. How many regions can you distinguish?
6. Is the head sharply marked off from the body proper or TRUNK?
7. *Note.* — There is one pair of eyes on the dorsal side of the head. (Not plainly visible!)
8. What appendages do you find on the head?
9. How many antennæ are there and where are they located?
10. *Note.* — The legs of the first segment of the body are modified to act as jaws, and hence are called MAXILLIPEDS or foot-jaws.
 - a. Describe the maxillipeds more accurately.
11.
 - a. How many segments are there in the trunk?
 - b. Compare the segments in the fore part of the trunk with those of the hind part.
12.
 - a. How many appendages are there on each segment?
 - b. Do any segments lack appendages?
13. Are the appendages all in one piece?
14. Are the legs all of the same length?

Drawing. — Dorsal view ($\times 3$).

Label. — Head, trunk, antennæ, maxillipeds, legs and segments of trunk.

TABULAR COMPARISONS BETWEEN INSECT, SPIDER AND
CENTIPEDE.

1. Where is the skeleton located?
2. Is the body segmented?
3. Name the regions of the body.
4. Is the body bilaterally symmetrical?
5. What segments bear appendages?
6. How many appendages are there on a segment?
7. What is the total number of legs?
8. Are the legs jointed?
9. How many eyes are there?
10. How many antennæ do you find?

CRAYFISH.

ANATOMY.

Materials. — Formol specimens of *Cambarus* sp.

1. Describe the skeleton in location and consistency.
2. What must a crayfish do before it can increase in size?
3. Is the body segmented?
4. How many regions can you distinguish in the body?
5. *Note.* — The anterior region is called the **CEPHALO-THORAX**: the posterior region, the **ABDOMEN**.
 - a. Compare the cephalo-thorax with the abdomen in length, thickness and structure.
6. How many segments do you find in the abdomen?
7. a. Compare, in the third abdominal segment, the dorsal with the ventral surface. (Do the surfaces have the same consistency?)
8. In what directions are the segments movable and why are they movable in these directions only?
9. *Note.* — The appendages attached to the abdomen are the **PLEOPODS** or swimmerets.
 - a. How many pleopods are attached to a segment?
10. *Note.* — Each pleopod consists of three pieces: an attached portion or **BASIPODITE**, and two branches, an outer or **EXOPODITE** and an inner or **ENDOPODITE**.
11. How do the **UROPODS**, the appendages on the segment next to the last, differ from the other appendages?
12. Compare the last segment or **TELSON** with the other segments of the abdomen.
13. *Note.* — The telson and the uropods together make up the **CAUDAL FIN**.

14. Are all the abdominal appendages built on the same general plan, viz., a basal piece and two branches?
15. *Note.*—Parts having a common origin or built on the same general plan, no matter what their use, are said to be **HOMOLOGOUS**.
16. *Note.*—In the male, the first two pairs of pleopods are long, while in the female they are rudimentary (very small).
 - a. Compare a male with a female in breadth of abdomen.
17. *Note.*—The cephalo-thorax is covered by the **CARAPACE**, which is divided by a groove into a head and a thoracic part.
 - a. Determine the relative size of the two parts.
18. *Note.*—The pointed projection of the carapace in front, is called the **ROSTRUM**.
 - a. Locate and describe the rostrum more exactly.
19. How many pairs of appendages are attached to the thorax?
20. *Note.*—The legs of the first pair are called **CHELIPEDS**, (pincer legs).
 - a. Compare the first leg with the second, and the second leg with the fifth.
21. Is the carapace attached to the body near the legs?
22. *Note.*—The space above the legs, between the carapace and the body, contains the **GILLS** or breathing organs and is called the **GILL CHAMBER**.
 - a. How could water get to the gills?
 - b. Tell the advantages of having the gills so placed?
23. *Note.*—In front of the legs are three pairs of foot-jaws or **MAXILLIPEDS**; then two pairs of thin **MAXILLÆ** and one pair of short, hard **MANDIBLES**.

- a.* Do the mandibles bear palps?
 - b.* Locate the mouth.
 - 24. *a.* Locate the antennæ with reference to the rostrum.
b. Describe the exopodite and endopodite in the antennæ.
 - 25. *Note.*—The whitish, perforated cone on the base of the antenna, marks the opening of the GREEN GLAND or KIDNEY.
 - a.* How many kidneys are there?
 - 26. Compare the ANTENNULÆ ('small feelers') with the antennæ in size, structure, shape and position.
 - 27. *a.* Locate the eyes with reference to the rostrum.
b. To what extent are the eyes movable and how is this movement made possible?
 - 28. Compare the eyes of the crayfish with those of the grasshopper in size, position and range of vision.
 - 29. In a specimen with the carapace cut away above the gills, describe the extent of the gill cavity.
 - 30. *Note.*—The feather-like structures are the GILLS.
 - a.* Describe a gill more accurately in form and structure.
 - b.* How many gills do you find on one side?
 - c.* How many gills are attached to the legs?
 - d.* Are any gills attached to the body?
 - e.* Are the gills external or internal structures. Give reasons.
 - 31. Do the thoracic appendages have exopodite and endopodite?
- Drawings.*—I. Entire animal from the left side ($\times 1$).

Label. — Cephalo-thorax, abdomen, groove, antenna, antennule, eye, rostrum, cheliped, legs, telson, uropod.

II. Ventral views of caudal fin, first and second abdominal appendages and second and fourth thoracic appendages ($\times 1$).

ACTIVITIES.

Materials. — Deep, oblong dishes of fresh water; living crayfish; pipettes; vials of carmine ground in water; beef juice, dilute acetic acid.

32. What is the color of the living animal?

I. LOCOMOTION.

Direction. — Let the animal walk on the table.

33. *a.* Which appendages are used in walking?
b. Are the chelipeds of aid in walking?
c. Does the animal drag any part of the body in walking? If so, name such parts.

Direction. — Let the animal walk in a dish of water.

34. *a.* Does the animal drag any part of the body now?
b. Explain the different ways of carrying the body in the water and on the table.
35. *a.* Study the movement of each pair of legs. Do the legs of the fifth pair move forward together or alternately? Answer the same question for each of the other pairs.
- b.* Which legs move forward at the same time on the right side of the body?

Direction. — Place the animal on its back in the water.

36. By what means is the normal position regained?
37. What methods of locomotion does the crayfish use?

II. BREATHING.

Direction. — Leave the animal on the table for about a minute; then place it quickly under water, noting what happens.

38. At what point do the bubbles appear?

Direction. — Hold the animal ventral side up while some carmine is poured under the carapace. Put the animal under water, and note where the carmine reappears.

39. Where does the carmine reappear and in what direction does it flow?
40. Make a diagram showing the course of water over the gills.
41. *Note.* — The water is drawn over the gills by the movement of little 'bailers' attached to the mouth parts.

III. SENSES.

Direction. — Touch the following surfaces lightly with a pencil: antennæ, antennulæ, eye, carapace, dorsal surface of the abdomen.

42. What result do you get in each case?
43. *a.* How are the antennæ carried by the animal when at rest?
- b.* How does the animal carry the antennæ in walking on the table?
- c.* What do you infer as to the use of the antennæ?

44. Does the crayfish, while walking in the water, avoid objects before touching them?

Direction. — Hold your hand between the crayfish and the light.

45. What does the crayfish do?

Direction. — Darken half of the tray and test whether a crayfish appears able to distinguish light from darkness.

46. *a.* Leave the crayfish in the light half of the tray for three minutes. What is the result?
b. Put the crayfish in the dark end of the tray for three minutes. What is the result?
c. Which does the animal seem to prefer, light or darkness?

Direction. — Hold the animal ventral side up and allow a drop of beef juice to fall upon the mouth parts.

47. What does the crayfish do?

Direction. — After a short time drop some very dilute acetic acid on the mouth parts.

48. How do the results compare with those observed in using beef juice?
49. Can a crayfish distinguish 'good' and 'bad-tasting' substances?

COMPARISONS BETWEEN CRAYFISH AND GRASSHOPPER.

1. Where is the skeleton located?
2. Is the body segmented?
3. How many appendages are there on each segment?
4. Name the regions of the body.
5. How many pairs of antennæ are there?
6. How many compound eyes?
7. Are the eyes fixed or movable?
8. How many simple eyes?
9. In what direction do the jaws work?
10. Do the mandibles bear palps?
11. Are there appendages on the abdomen?
12. Are the legs jointed or all in one piece?
13. What kind of breathing organs are there?
14. Are the appendages single or forked at the end?
15. Is the body bilaterally symmetrical?

SOW-BUG.

Materials. — Alcoholic specimens of *Oniscus* sp.

1. *a.* What is the shape of the body?
b. What shape would be shown by a slice taken across the body?
2. Is the sow-bug a segmented animal? Why?
3. *a.* What regions can you find in the body?
b. What fraction of the whole body is comprised in each region?
4. Describe the skeleton in location and consistency.
5. Is the head movable? If so, in what directions?
6. Describe the eyes in number, size and location.
7. Describe the antennæ as to number, size and shape.
8. *a.* How many segments are there in the thorax?
b. Compare the anterior segments with the posterior as to size and shape.
c. How many segments of the thorax carry appendages?
d. How many appendages are there to a segment?
9. Describe the legs in size, shape, structure and place of attachment to the body.
10. Compare the anterior with the posterior legs in shape and size.
11. *Note.* — In the female, the thorax bears overlapping plates attached to the bases of the legs. A BROOD-POUCH for carrying the eggs is thus provided.
a. What advantages are gained through carrying the eggs around till the young are hatched?
12. *Note.* — On the ventral side of the abdomen are flat plates covering the gills or breathing organs.

a. What is the advantage of having the gills placed as they are?

13. Is the sow-bug bilaterally symmetrical? Why?

Drawing. — Entire animal, left lateral view ($\times 5$).

Label. — Head, antennæ, eyes, thorax, legs.

COMPARISONS BETWEEN CRAYFISH AND SOW-BUG.

1. Is the body bilaterally symmetrical?
2. Where is the skeleton located?
3. Is the body segmented?
4. Do the segments differ markedly from each other?
5. How many regions can you distinguish in the body?
6. Are the eyes stalked?
7. Are the legs all alike in size and shape?
8. Name the smallest region in the body.
9. Does the abdomen bear appendages?
10. Where are the gills located?

ANNULATA.

EARTHWORM.

Materials. — Live specimens of *Lumbricus* sp.; shallow trays; rulers.

1. What is the general shape of the body?
2. *a.* What is the color of the worm?
b. Is the entire body colored the same?
c. What advantage is the color to the worm?
3. *a.* Is the body segmented?
b. Compare the segments of the anterior end with those of the posterior end in size and shape.
4. Compare the anterior and posterior ends of the worm in size, shape, activity and sensitiveness to touch.
5. Can you easily distinguish regions in the body?
6. *a.* Measure with a ruler a worm when contracted (drawn together). How long is it?
b. Measure the same worm when extended (stretched out). How long is it?
c. How do you account for the difference in length?
7. Do the large worms have the same number of segments as the small ones? (Count and see.)
8. *Note.* — The broad, light-colored band about the worm is called the **GIRDLE**. It forms a case for the eggs when they are laid.
 - a.* Near which end of the animal is the girdle?
 - b.* How many segments are included in the girdle?

9. *Note.*—The body is provided with several rows of tiny bristles, the *SETÆ*, which aid in locomotion.
- On which surface of the body are the setæ located?
 - How many rows of setæ do you find?
 - How many setæ to a segment?
10. *Note.*—The *FOOD TUBE* or *GUT* is a nearly straight tube extending the entire length of the body.
- Describe the mouth in shape and position.
 - Are hard jaws present?
11. *a.* Describe the dorsal blood tube in color and position.
- Is there a similar tube visible elsewhere in the body? If so, describe its position.
14. *a.* Describe briefly by what means the worm seems to move.
- Does the same end always go forward?
 - Of what use is the slimy material on the surface of the body?
15. *Direction.*—Cover half the dish, leaving the worm in the light half for five minutes.
- What does the worm do?
 - State your conclusions regarding the response of the worm to light and to darkness.
16. Is the worm a bilaterally symmetrical animal? Give all your reasons.
- Drawing.*—Five segments, showing the number and arrangement of the bristles ($\times 5$).

SAND WORM.

Materials — Living specimens of *Nereis* sp.; shallow trays; sea water. Specimens preserved in 4 per cent chromic acid.

ANATOMY.

1.
 - a. Describe the shape and general appearance of the worm.
 - b. What would be the shape of a cross-section of the body?
2.
 - a. Into how many segments is the body divided?
 - b. Do the long and the short worms have the same number of segments?
 - c. How do the various segments compare with each other in size and shape?
3.
 - a. Name the regions of the body.
 - b. How much relative space is devoted to each region?
 - c. How can you distinguish the dorsal from the ventral surface?
4. *Note.* — The fleshy appendages at the side of the body are called **PARAPODIA** ('side-feet').
 - a. How many parapodia do you find to a segment?
 - b. Does every segment bear parapodia?
5. *Note.* — A parapodium bears bristles (**SETÆ**) as well as a flat triangular piece, the **GILL**.
 - a. Describe the general shape of a parapodium.
 - b. Describe the position of the gill and the setæ respectively.
 - c. Compare the earthworm and sand worm as to the number of bristles on a segment.

6. *Note.*—The head is made up of two regions: a part in front of the mouth (PROSTOMIUM), and a part surrounding the mouth (PERISTOMIUM).

a. Describe the shape of the prostomium as seen from the dorsal side.

b. Describe the shape of the peristomium.

c. Do either of the head segments bear parapodia?

7. *Note.*—The short, thick appendages of the head are called PALPS; the long, thin appendages are called TENTACLES.

a. How many palps and how many tentacles do you find?

8. *Note.*—The small black dots on the dorsal surface of the prostomium are the EYES.

a. How many eyes do you see?

9. a. Describe the position of the mouth.

b. Where are the jaws when not visible?

Drawing.—The first five segments of the body, dorsal view ($\times 5$).

Label.—Prostomium, peristomium, palps, tentacles, parapodia, setæ, eyes.

ACTIVITIES.

I. LOCOMOTION.

10. *Note.*—The motion of the sand worm may be described as writhing.

a. When the animal is swimming rapidly, how many 'bends' do you find in the entire length of the body?

b. How many 'bends,' when the worm is swimming slowly?

- c.* At which end of the body does the wave of writhing begin?
- 11. Can you determine how the parapodia are used when the worm is swimming?

II. CIRCULATION OF THE BLOOD.

- 12. *a.* In which direction does the blood flow in the dorsal blood tube?
 - b.* How can you tell it is flowing at all?
- 13. *a.* Fix your attention on one point of the tube and count the number of beats in one minute.
 - b.* Now count the number of beats per minute in your own pulse.
 - c.* Compare the frequency of your pulse with that of the sand worm.

III. SENSES.

- 14. *Direction.* — Touch the following parts of the body lightly with your pencil and note results: (1) the anterior end; (2) the posterior end; (3) one of the parapodia.
 - a.* Which is the most sensitive region of the body?
- 15. *Direction.* — Darken one half of your tray. Put the worm in the light end of the tray and leave it for three minutes.
 - a.* What result do you obtain?
- 16. *Direction.* — Put the worm in the dark end of the tray for three minutes.
 - a.* What is the result?
- 17. State briefly your conclusions regarding the response of the worm to light and to darkness.

COMPARISONS BETWEEN EARTHWORM AND SAND WORM.

1. Is the body bilaterally symmetrical?
2. Is the body segmented?
3. How many regions in the body?
4. Do you find appendages?
5. In which worm are the bristles (*setæ*) more numerous?
6. Are eyes visible?
7. Are appendages found on the anterior end of the body?
8. Are jaws present?
9. Which is the 'higher' animal? Why?

COMPARISONS BETWEEN WORM, CRAYFISH AND
GRASSHOPPER.

1. Is the body bilaterally symmetrical?
2. Is the body segmented?
3. Are the segments all alike?
4. Name the regions of the body.
5. Are appendages present on each region?
6. How many appendages to a segment?
7. Is there a skeleton? If so, where is it located?
8. Is there a distinct head?
9. What appendages are found on the head?
10. Are jaws present?
11. Are the walking appendages similar in size and shape?
12. What kind of breathing organs do you find and where are they located?
13. Are any of the appendages homologous in the different animals?
14. What appendages are analogous (similar merely in function)?

MOLLUSCA.

HARD-SHELLED CLAM.

Materials. — Unopened specimens of *Venus mercenaria*; empty shells; single valves; clams 'on the half shell,' preserved in 5 per cent formol.

I. EXTERNAL SURFACE OF THE SHELL.

1. *Note.* — The body is covered completely by a limy shell, consisting of right and left halves or VALVES. Such a shell is a BIVALVE.

a. Describe the outline of the shell as seen from the side.

b. What is the outline as seen from the end?

c. Do the valves differ in size and shape?

2. *Note.* — The valves are joined on the dorsal side by the HINGE LIGAMENT.

a. Compare the dorsal side of the clam with the ventral side in thickness.

b. On which side do the valves open?

c. Describe the hinge ligament in texture, size and color.

3. *Note.* — The beak-like prominences or UMBONES (sing., umbo) point toward the anterior end of the shell.

a. Compare the anterior with the posterior end in outline.

- b.* How would you hold the shell to determine the right and the left valve?
4. *Note.*—The ridges regularly arranged on either valve are called the **LINES OF GROWTH**.
- a.* How are the lines of growth arranged with reference to the edge of the shell?
- b.* How are they arranged with reference to the umbones?
- c.* What part do you consider to be the oldest region of the shell, and why?

II. INTERNAL SURFACE OF THE SHELL.

5. Compare the inner and outer surfaces as to color and smoothness.
6. *Note.*—Near the dorsal edge of the shell are found irregular projections called the **HINGE TEETH**.
- a.* How many hinge teeth are found on each valve?
- b.* Close the valves and tell what relation the hinge teeth bear to each other.
- c.* What are the advantages of the hinge teeth?
7. *a.* Is the hinge ligament attached to the outside or to the inside of the valve?
- b.* Why are the shells of dead bivalves always gaping?
8. *Note.*—Near the anterior end of the shell is found a **SCAR** marking the attachment of an **ADDUCTOR MUSCLE**.
- a.* Is there a posterior adductor muscle scar also?
9. *Note.*—The line joining the muscle scars is called the **MANTLE LINE**, because it marks the attachment of the mantle to the shell.
- a.* Is the mantle line a uniform curve?

Drawings. — I. External lateral view of a single valve
($\times 1$).

Label. — Umbo; lines of growth; hinge ligament;
dorsal, ventral, anterior and posterior edges.

• II. Internal lateral view of a single valve
($\times 1$).

Label. — Hinge teeth; hinge ligament; muscle scars;
mantle line; dorsal, ventral, anterior and posterior edges.

III. BODY IN THE SHELL.

10. *Note.* — The thin membrane concealing the body is a lobe of the MANTLE.

a. Do you find a similar lobe on the opposite side of the body?

b. Where is the mantle attached to the shell and where unattached or free?

c. Is the mantle of equal thickness in every part?

11. a. Describe the adductor muscles in appearance and consistency.

b. By what means are the valves separated and by what means brought together?

12. *Note.* — At the posterior edge of the mantle are situated dark colored tubes or SIPHONS.

a. How many siphons are there?

b. How are they located with reference to each other?

13. *Note.* — The space between the right and left lobes of the mantle is the MANTLE CAVITY which contains the body proper or VISCERAL MASS.

a. What is the consistency of the visceral mass?

b. Is the visceral mass segmented?

c. Do you find distinct regions in it?

14. *Note.*—The flat, plate-like structures between the visceral mass and the mantle are the GILLS.

- a. Describe a gill in form and structure.
- b. How many gills do you find on one side?
- c. Is the number the same on either side?
- d. Which is the larger, the inner or the outer gill?

15. *Note.*—The fleshy outgrowth on the ventral side of the visceral mass is the locomotor organ or Foot.

- a. Describe the foot in size, color and consistency.

16. *Note.*—Surrounding the mouth is found a number of fleshy flaps, the PALPS.

- a. How many palps are there?

Drawing.—The body in the shell, mantle removed from one side ($\times 1$).

Label.—Adductor muscles, gills, visceral mass, foot, palps, edge of mantle.

UNIVALVE SHELL.

Materials. — Shells of *Fulgur* sp. and *Polynices* sp.

1. What is the outline of the shell as seen from the side, with the opening or **APERTURE** turned toward you?
2. Describe the shell's outline as seen from the pointed end or **APEX**.
3. *a.* Describe the shape of the aperture.
b. What is the character of the aperture's outer lip? Is it entire, scalloped, wavy or jagged?
4. *Note.* — In some shells the aperture is drawn out at the base into a long grooved projection, the **POSTERIOR CANAL**, which lodges the siphons.
a. Describe the posterior canal, if your specimen shows one.
5. *Note.* — The shell consists of a central axis or **COLUMELLA** about which run the spiral turns or whorls.
a. How many complete turns are there from aperture to apex?
b. Do the turns run in a right-handed manner, like the hands of a watch, or in a left-handed direction?
6. *Note.* — When the columella is hollow, it has at its base an opening called the **UMBILICUS**.
a. Describe the umbilicus, if your specimen shows one.
7. *Note.* — The lowest turn of the shell contains the animal's body and is hence called the **BODY WHORL**, the rest of the shell being the **SPIRE**.
a. Compare the body whorl with the spire in size.
8. *Note.* — The boundary line between two adjacent turns is the **SUTURE**.

- a. Describe the suture. Is it depressed or elevated?
9. Which is the oldest part of the shell? How do you know?
10. Judging from the shape of the shell, would you expect a univalve mollusk to be symmetrical? Give your reasons.
11. Describe the direction and shape of the lines of growth.

Drawing. — Lateral view of the shell with the aperture turned toward you ($\times 1$).

Label. — Apex, spire, aperture, suture, outer lip, body whorl, posterior canal.

COMPARISONS BETWEEN GRASSHOPPER, EARTHWORM OR
SAND WORM AND CLAM.

1. Where is the skeleton located?
2. Is the animal bilaterally symmetrical?
3. Is the animal segmented?
4. Can regions be distinguished in the body? If so, how many?
5. Is there a distinct head?
6. Are appendages present on the head? If so, how many?
7. How many appendages are found on the trunk?
8. What locomotor organs do you find?
9. To what region of the body are they attached?
10. What breathing organs are present?
11. What distinct sense organs do you find?

ECHINODERMATA.

STARFISH.

Materials. — Either dry or wet specimens of *Asterias vulgaris*, preserved in 5 per cent formol.

1. *a.* Describe the shape and general appearance of the starfish.
b. Is the shape the same in every specimen?
2. Describe the skeleton in location and consistency.
3. *Note.* — The central part of the body is called the Disc; the radiating arms are the RAYS.
 - a.* Describe the shape of the disc.
 - b.* How many rays are there in your specimen?
 - c.* Are the rays all alike in size and shape?
 - d.* Is the number the same in every specimen?
4. *Note.* — A body which has its parts arranged about a common centre is said to show RADIAL SYMMETRY.
 - a.* What kind of symmetry do you find in the starfish?
Give reasons for your answer.
5. *Note.* — The side upon which the mouth is found is the ORAL surface; the opposite surface is the ABORAL.
 - a.* Describe the position of the mouth.
 - b.* What structures do you find about the mouth?
6. *Note.* — The small wart-like prominence on the aboral surface is the MADREPORITE.
 - a.* Locate the madreporite more exactly.

- b. Describe the madreporite in outline, color and structure.
7. *Note.*—The two rays lying one on either side of the madreporite are the *BIVUM*; the remaining rays are the *TRIVUM*. The middle ray of the trivium is called the *ANTERIOR* ray.
- a. Can you pass a plane through the madreporite so as to divide the body into two corresponding parts? How would such a plane pass?
- b. Could you consider a starfish as bilaterally symmetrical as well as radially symmetrical?
8. Describe the structure and distribution of the hard *SPINES* on the aboral surface.
9. *Note.*—Near the base of the spines are short projections, the *PEDICELLARÆ*. Between the spines lie soft, hollow projections, the *RESPIRATORY CÆCA* (not visible in dry specimens).
10. Compare the spines on the oral surface with those on the aboral side. Do you find any definite arrangement? If so, where?
11. *Note.*—The depression running along the oral side of a ray is called the *AMBULACRAL GROOVE*.
- a. How are the grooves related to the area about the mouth?
- b. Compare the inner end of a groove with its outer end.
12. *Note.*—In the grooves lie rod-like structures, the *TUBE FEET*, which aid in locomotion.
- a. Describe the shape of a tube foot.
- b. What can you say of the number and arrangement of the tube feet?
13. *Note.*—Near the outer end of each groove is found an *EYE SPOT*.

a. Describe the eyes in position and color.

Drawings. — I. Aboral surface ($\times \frac{3}{4}$).

Label. — Disc, anterior ray, bivium, trivium, spines, madreporite.

II. Oral surface ($\times \frac{3}{4}$).

Label. — Grooves, tube feet, mouth, spines.

COMPARISONS BETWEEN GRASSHOPPER, EARTHWORM,
CLAM AND STARFISH.

1. Is the body segmented?
2. What is the general shape of the animal?
3. What kind of symmetry does the body show?
4. Name the regions of the body.
5. Where is the skeleton located?
6. What kind of locomotor organs are there?
7. What breathing organs are found?
8. What sense organs do you see?

COELENTERATA.

SEA ANEMONE.

Materials. — Specimens of *Metridium* sp. preserved in formol. Entire animals, longitudinal sections and cross-sections.

1. Describe the body in shape and consistency.
2. *Note* — The animal during life is usually fixed by its broad
BASE to a rock or other support.
 - a. Describe the base more exactly.
3.
 - a. Describe the location and shape of the MOUTH.
 - b. What structures do you find surrounding the mouth?
 - c. Are these organs all of the same size?
 - d. Where do you find the largest of these organs?

(Cross-section.)

4. What is the shape of the cross-section?
5. What kind of symmetry do you find?
6. Describe the position and shape of the food tube
or GULLET.
7. *Note.* — The fleshy partitions connecting the gullet with the
body wall are called the primary MESENTERIES.
 - a. How many complete or primary mesenteries are there?
 - b. Are there any mesenteries which do not reach the
gullet? If so, how many?

c. Are the primary mesenteries single or double structures?

8. *Note.* — The chambers surrounding the gullet and communicating with it below, are the CŒLOMIC or INTER-MESENTERIC CHAMBERS.

(Longitudinal Section.)

9. How does the gullet compare in length with the whole body?
10. Does the gullet have more than one large opening on the surface of the body?
11. Describe the course which liquids would take in passing from the mouth to the interior of the hollow tentacles.

Drawings. — I. A longitudinal section ($\times 1$).

Label. — Mouth, tentacles, base, oral end.

II. A cross-section ($\times 1$).

Label. — Body wall, gullet, mesenteries, cœlomic chambers.

HYDROID.

Materials. — Small vials, each containing a piece of a colony of *Pennaria* sp. in 5 per cent formol.

1. *Note.* — When several individuals are more or less closely associated, the whole group is called a COLONY.

a. Describe the general appearance of a hydroid colony.

b. What is the color of the main stalk?

c. Is the branching of the stalk opposite or alternate?

2. *a.* Where are the individual animals or POLYPS situated?

b. Are the polyps of the same color as the stalk?

3. *Note.* — The fine thread-like structures stretching out from a polyp are called TENTACLES.

a. Do all the individuals bear tentacles?

4. *Note.* — The smooth globular structures are REPRODUCTIVE INDIVIDUALS.

5. What are the advantages to an individual of living in a colony?

Drawing. — Side view ($\times 5$).

Label. — Stalk, lateral branches, polyps, tentacles, (reproductive individuals).

MEDUSA.

Materials. — Small vials containing specimens of *Goniomena* sp. in 5 per cent formol.

1. Describe the shape and general appearance of the body.
2. What kind of symmetry do you find?
3. *Note.* — The outer, rounded part of the body is called the **BELL** or **UMBRELLA**, which has attached to its edge the **TENTACLES**.
 - a. Describe the tentacles in size and shape.
 - b. How many tentacles do you find in your specimen?
 - c. Is the number the same in every specimen?
4. *Note.* — The open side of the bell is partially closed by a perforated plate, the **VELUM**.
 - a. Describe the shape of the opening in the velum.
 - b. How much space is occupied by the opening and the velum, respectively?
5. *Note.* — The central stalk inside the bell is the handle or **MANUBRIUM**, which bears the **MOUTh**.
 - a. Describe the location of the mouth more exactly.
 - b. Describe the shape and color of the manubium.
6. *Note.* — The opaque structures seen through the bell are the **GONADS** or reproductive organs.
 - a. Describe the gonads in number, shape and arrangement.
7. What advantage is the transparency of its body to the animal?

Drawings. — I. Side view ($\times 4$).

Label. — Umbrella, tentacles, gonads, manubrium.

II. A view from the flat side ($\times 4$).

Label. — Velum, manubrium, mouth, gonads, tentacles.

CORAL.

Materials. — Small pieces of staghorn coral, clam shell, dried starfish; some limy sponges and powdered chalk; hydrochloric acid. Lenses.

1. Describe the color and consistency of the given piece of coral.
2. (Demonstration.) Test with acid, pieces of chalk, starfish, sponge, clam shell and coral. What happens in each case?
3. *Note.* — Substances which act in the same way under the same circumstances are considered to have the same chemical composition. Chalk consists of a substance called CALCIUM CARBONATE (related to lime).
 - a. Of what substance is coral made? Give reasons for your answer.
4. Describe the shape of the large mass of coral shown to you.
5. Is the main stalk solid?
6. *Note.* — Coral is formed by a colony of polyps, the several polyps being connected by stalks of living matter.
 - a. What proof have you that polyps once lived in the coral?
 - b. About how many polyps lived in the mass you are studying?
7. *Note.* — The wall of the cuplike cavity within which a single polyp lived is called the THECA.
 - a. What structures do you find within the theca?
 - b. How many of these structures are there?
 - c. How are they arranged?
 - d. To what parts in the sea anemone do these structures appear to correspond?

8. What peculiar method of reproduction makes possible coral formation on a large scale?

Drawings. — I. A general view ($\times 1$).

II. A single theca, side view ($\times 10$).

III. A single theca, viewed from above ($\times 10$).

PORIFERA.

LIMY SPONGE.

Materials. — Small vials, each containing an entire specimen of *Grantia* sp., a cross-section and a longitudinal section, in 5 per cent formol or 70 per cent alcohol; prepared slides of spicules; microscopes.

1. *a.* What is the shape of the body?
b. Is the specimen perfectly regular in shape?
2. Do you find any evidence of budding in the sponge?
If so, from what part of the parent sponge do the buds grow?
3. *Note.* — The sponge is attached by one end to a rock or other object, while the free end bears the excurrent opening or **OSCULUM**.
a. How many oscula are there in your specimen?
4. *Note.* — The soft parts of the sponge have imbedded within them little limy pieces or **SPICULES**.
a. Describe the appearance of the spicules about the osculum.
b. Of what use are the spicules to the sponge?
c. Describe the appearance of the spicules as seen under the microscope.

IN CUT SECTIONS OF THE SPONGE.

5. The cavity in the sponge is called the **CLOACA**.
a. How far does the cloaca extend into the body?

- b.* What is the shape of the cloaca in cross and in longitudinal section?
6. *Note.* — Water passes almost continually, through tiny holes or PORES in the side of the body, into the cloaca and out through the osculum.
- a.* Make a diagram showing the course of water through the body of the sponge.
- b.* What is the use to the sponge of this current of water?

Drawings. — I. and II. Longitudinal and cross-sections ($\times 4$).

Label. — Osculum, body wall, cloaca, spicules.

III. A few spicules as seen under the compound microscope.

BATH SPONGE.

Materials. — Small bath sponges; slides of fibers teased out and stained with acid fuchsin.

1. Describe the consistency of the dried sponge.
2. What effect does water have upon the sponge?
3. Do you find any oscula? If so, how many?
4. Find and describe the little openings or pores.
5. *Note.* — The framework of the bath sponge consists of a mass of horny fibers.
 - a. Describe the fibers in color and texture.
 - b. Describe a piece of fiber as seen under the compound microscope.
 - c. Are the fibers connected, or separate from each other?
 - d. Of what use are the fibers to a sponge?
 - e. Compare the fibers of the bath sponge with the spicules of the limy sponge.

Drawing. — A bit of horny fiber as seen under the compound microscope.

COMPARISONS BETWEEN MEDUSA, HYDROID, ANEMONE
AND SPONGE.

1. Is the animal free-moving or fixed?
2. Do the animals live singly or in colonies?
3. What kind of symmetry do you find?
4. What general shape does the animal show?
5. How many openings do you find in the body?
6. *a.* What organs are used for grasping food?
b. What can you say of the number of such organs?
7. What organs of locomotion do you find, if any?

COMPARISONS BETWEEN GRASSHOPPER, SAND WORM,
CLAM, STARFISH AND MEDUSA OR ANEMONE.

1. What kind of symmetry do you find?
2. Is the body made up of segments?
3. Does the body show distinct regions?
4. *a.* How many regions are there in the body?
b. What are the names of the regions?
5. Does the body bear appendages?
6. Name the appendages of each region?
7. What kind of a skeleton is there?
8. What locomotor organs do you find?
9. What sense organs are present?
10. What food-taking organs are there?

PROTOZOA.

SLIPPER ANIMALCULE.

Materials. — Hay infusion containing *Paramœcium* sp.; slides and cover glasses; compound microscopes; Leuckart chart.

Direction. — Let half the class work with the microscopes while the other students use the chart.

I. WORK WITH THE MICROSCOPE.

1. Are all the animals of the same size and shape?
2. What is the color of the body?
3. Describe in a general way the speed with which the animals move.
4. Is the rate of speed always the same?
5. By what means do the animals move?
6. What change of form, if any, does the body undergo in passing through narrow places?
7. Does the animal always keep the same surface uppermost?
8. Does it always move with the same end forward? If so, which end?

II. WORK FROM THE CHART OR BOARD.

- i. *Note.* — The body of the Slipper Animalcule is made up of a single mass of living matter or PROTOPLASM: such a mass of living matter is called a CELL. The bodies of

the animals thus far studied are composed of vast numbers of cells.

2. *a.* Describe the outline of the body.
b. What is the ratio of length to width?
c. Compare the ends of the body in point of shape.
3. *Note.* — The small, hair-like bodies covering the surface of the cell are called *CILIA* (sing. *cilium*).
a. What can you say of the number of cilia?
4. Is there any definite point at which food is taken into the body?
5. *Note.* — The large, clear area at either end is the *CONTRACTILE VACUOLE*. These vacuoles apparently serve to expel waste from the body.
a. How many contractile vacuoles do you find?
6. *Note.* — The smaller bodies filled with granules, scattered about in the cell, are *FOOD VACUOLES*.
a. What can you say of the number of food vacuoles?
7. *Note.* — A typical cell contains a small body called the *NUCLEUS*.
a. Can you find a nucleus in the Slipper Animalcule?
If so, describe its location and shape.

Drawing. — Make a figure of the Slipper Animalcule, three inches in length.

Label. — Cilia, contractile vacuoles, food vacuoles, nucleus, food opening (if one be shown).

VERTEBRATA.

LIVING FISH.

Materials. — Small glass jars containing 'goldfish.'
(This exercise may be profitably used during an excursion to the Aquarium.)

1. Describe the outline of the body as seen from the side.
2. What is the shape of the body as seen from the anterior end?
3. *Note.* — The body is covered with thin plates called **SCALES**.
 - a. How are the scales arranged with reference to each other?
4.
 - a. How many distinct regions does the body show?
 - b. Does the fish have a neck?
5.
 - a. What organs of locomotion do you find?
 - b. How many of these organs are paired and how many unpaired or single?
 - c. Do the paired fins show joints similar to those in the human arm or leg?
6. *Note.* — The anterior pair of fins are called the **PECTORAL** fins; the posterior pair are the **PELVIC** fins.
 - a. With what structures in a dog or cat would you compare these fins?
7. *Note.* — The unpaired fins are called **DORSAL**, **ANAL** and **CAUDAL**, according to the region of the body on which they are placed.
 - a. Describe each of these fins more fully in size, shape and position.

8.
 - a. What fins does the fish use in swimming forward?
 - b. What fins are employed in turning around?
 - c. What fins are used by the fish in going backward, or in remaining in one place?
 - d. Which of the fins is most effective in locomotion, and why?
9.
 - a. Describe the position of the mouth.
 - b. What is the shape of the open mouth as seen from the anterior end?
 - c. What is the shape of the closed mouth when viewed as before?
10.
 - a. Describe the number, position and arrangement of the nostrils (NARES) with reference to the mouth.
 - b. How do the fish's nostrils compare with your own in the above respects?
11.
 - a. Describe the eyes in number and location.
 - b. How do they compare in location with your own?
 - c. Are the eyes of the fish movable?
 - d. Compare the angle of vision in the fish with that in man.
 - e. Are there eyelashes or eyelids in the fish?
 - f. How are the fish's eyes protected?
 - g. What are the advantages to a fish of having sense organs, like the eyes and the nostrils, placed near the mouth?
12. *Note.*—The red GILLS are located on either side of the head under the gill-cover or OPERCULUM.
 - a. Does the fish open and close its mouth when not feeding?
 - b. If so, where does the water escape that has been taken in at the mouth?

- c. Over what organs would the water pass?
- d. Describe the position of the opening through which the water passes, with reference to the operculum.

Drawing. — A lateral view, four inches in length.

Label. — Head, trunk, scales, the dorsal, anal, caudal, pectoral and pelvic fins, nostril, eye, operculum.

FROG.

ACTIVITIES.

Materials.—Live frogs in battery jars containing a little water.

1.
 - a. Is the frog all of one color?
 - b. What is the advantage to the animal of its peculiar coloration?
 - c. Do you find outgrowths from the skin, such as scales or feathers?
 - d. With what substance is the skin covered?
2. What is the attitude of the frog when at rest?
3. How does the animal move when on land?
4.
 - a. To what extent are the eyes movable?
 - b. What is the advantage to an animal of movable eyes?
 - c. What is the use of the eyelids?
5. *Note.*—The motion of the skin under the mouth accompanies the pumping of air into the lungs.
 - a. Is the air taken in through the mouth?
 - b. Through what openings does the air enter?
 - c. How many breaths does the frog draw in a minute?
 - d. Compare the rate of breathing just observed with your own.

EXTERNAL CHARACTERS.

Materials. — Frogs killed with chloroform and preserved in five per cent formol. Human skull.

6. *a.* What is the shape of the body's outline in a dorsal view?
b. In a lateral view?
7. What kind of symmetry do you find?
8. Does the skin fit closely to the body?
9. *a.* How many regions does the body show?
b. Is there a distinct neck?
c. Is there a distinct tail?
10. How can you distinguish the dorsal from the ventral surface?
11. How many appendages do you find?
12. *a.* Compare the fore limb with the hind limb in length.
b. Compare, in the same way, the hind limb with the trunk.
13. *a.* Compare the fore limb of the frog with your own: do you find upper ARM, FOREARM, HAND and FINGERS?
b. How many fingers are there?
14. *a.* Compare the frog's hind limb with your own: can you distinguish THIGH, SHANK or LEG, FOOT and TOES?
b. How many toes has the frog?
15. *a.* How is the hind limb of the frog adapted or fitted for the work it has to do?
b. In what way is the frog's foot adapted for use in the water?
16. What is, in general, the shape of the head?
17. Describe the mouth in size and position.

18. Tell the size and position of the ANTERIOR NARES or nostrils.
19. Describe the eyes with reference to their size, shape and position on the head.
20. *Note.*— Behind the eye, on either side of the head, is a circular, depressed patch of skin, the ear-drum or TYMPANIC MEMBRANE.
 - a. Is the tympanic membrane easily visible from the outside in man?
21. *Note.*— The space, visible when the mouth is open, is the BUCCAL CAVITY.
 - a. What can you say of the size of the buccal cavity?
 - b. In what plane do the jaws move?
 - c. Are both jaws freely movable?
 - d. Compare the frog with man in these respects.
22.
 - a. Do you find teeth on the upper jaw, lower jaw, or roof of the mouth?
 - b. For what purpose are the teeth adapted?
 - c. Compare the frog with man as to the location of the teeth.
23. *Note.*— Bristles which are passed into the nostrils or ANTERIOR NARES, enter the buccal cavity through openings called the POSTERIOR NARES.
 - a. Compare the location of the posterior nares in the frog and man. (See prepared human skull.)
24. *Note.*— From the dorsal part of the buccal cavity, the so-called Eustachian tube passes outward, on either side, and expands beneath the corresponding tympanic membrane into the TYMPANIC CAVITY.
 - a. Locate and describe the Eustachian tubes more exactly.
 - b. What structure closes the Eustachian tube on the outer side?

25. *Note.* — On the floor of the mouth is the fleshy TONGUE.
- a. How and where is the tongue attached?
 - b. Compare the tongue, in shape and place of attachment, with that of man.
26. *Note.* — On the floor of the buccal cavity, behind the tongue, is a longitudinal slit, the GLOTTIS.
- a. Describe the glottis in location and length.
27. *Note.* — The glottis opens into a short WINDPIPE which communicates with the LUNGS.
- a. Through what cavities must air pass in going from the surface of the body to the lungs?
28. *Note.* — The hinder part of the buccal cavity is called the PHARYNX, which leads posteriorly into the gullet or ŒSOPHAGUS.
- a. Describe the pharynx in breadth.
29. What is the position of the CLOACAL APERTURE (the posterior opening of the digestive tract)?
- Drawing.* — I. Entire frog from the left ($\times 1$).
- Label.* — Head, trunk, fore limb, hind limb, mouth, eye, ear drum, nostril, color markings.

INTERNAL STRUCTURE.

Direction. — Place the frog on its back, cut through the skin along the middle line and separate the skin from the underlying muscles. Carefully cut through the muscles and expose the VISCERA or internal organs.

30. *Note.* — The large cavity containing the viscera is the CÆLUM or body cavity. The membrane or thin sheet of tissue which lines the cœlum is called the PERITONEUM.

a. Describe the peritoneum in surface texture, color and thickness.

31. *Note.* — The cœlom in man is divided by a muscular partition or shelf, the DIAPHRAGM, into two parts: an anterior part, the THORAX, and a posterior part, the ABDOMEN.

a. Do you find a diaphragm in the frog?

32. *Note.* — The HEART is the conical muscular organ lying near the middle of the body.

a. Describe the heart more exactly as to size, shape and position.

33. *Note.* — The LUNGS are soft, fleshy sacs lying dorsal to the heart.

a. How many lungs do you find?

b. Describe the lungs more fully as to thickness of wall, elasticity and shape.

34. *Note.* — The large, reddish-brown organ lying in the anterior part of the cœlom is the LIVER.

a. Describe the liver in size and shape.

b. How many LOBES or separate parts does the liver exhibit?

35. *Note.* — The small, greenish sac on the under side of the liver is the GALL BLADDER.

a. Describe the gall bladder more exactly in size and position.

Drawing. — II. The organs lying in position, as seen from the front ($\times 1$).

Label. — Heart, lungs, liver.

Direction. — Remove the liver carefully.

(In the FEMALE frog, take at this point Question 50; then remove the ovary and come back to Question 36.)

36. Is the food tube, digestive tract or GUT, of the same diameter throughout its extent?

37. *Note.* — The following names are given to the several regions of the gut, beginning at the anterior end: ŒSOPHAGUS or GULLET, STOMACH, SMALL INTESTINE, LARGE INTESTINE and CLOACA.

a. Describe the gullet in length and diameter.

b. Where does the gullet begin and where does it end?

38. Describe the stomach with regard to size, shape and connection with adjoining parts of the gut.

39. Describe the small intestine in length, diameter and relations to the surrounding organs.

40. a. Describe the large intestine with reference to length, diameter, color and course.

b. Is the change in diameter from small to large intestine sudden or gradual?

c. In what sense is the 'small' intestine smaller than the 'large'?

41. *Note.* — The double layer of peritoneum which carries the blood vessels, lymph tubes and nerves, and supports the intestine, is called the MESENTERY.

- a. Describe the mesentery in thickness, color, consistency and surface character.
42. *Note.* — The PANCREAS is a pale, irregular mass lying in the loop formed by the stomach and the small intestine.
- a. Describe the pancreas more exactly.
43. *Note.* — The SPLEEN is a small, dark-colored body, lying in the mesentery opposite the beginning of the large intestine.
- a. Describe the spleen more exactly as to shape and color.
- b. Is there a tube connecting the spleen with the intestine?
44. *Note.* — The terminal part of the large intestine, which receives the ducts of the kidneys, the oviducts and the bladder, is the CLOACA.
- a. Describe the cloaca in length and diameter.
45. *Note.* — The KIDNEYS are flattened bodies lying in the dorsal part of the cœlom.
- a. Describe the kidneys in shape, size, color and position.
- b. How many kidneys are there?
46. *Note.* — The URETER or duct of the kidney is a white, twisted tube connecting the kidney with the cloaca.
- a. Describe the ureter in length and diameter.
- b. With what part of the kidney is the ureter connected?
47. *Note.* — The BLADDER is a thin-walled sac situated in the posterior part of the cœlom and emptying into the cloaca.
- a. Describe the bladder in size, shape and color.

In the male frog.

48. *Note.* — The TESTIS or gonad of the male is a small, rounded, pale-colored body lying ventral to the kidney.

- a. How many testes do you find?
 - b. Describe the testis more fully in size and shape.
49. *Note.* — The FAT BODIES are yellowish, tufted masses lying near the gonads.
- a. How many fat bodies are there?
 - b. How are they located with reference to the gonads?

In the female.

50. *Note.* — The OVARY or gonad of the female is frequently so filled with eggs as to almost fill the cœlom.
- a. Describe the ovary in size, shape, position, color.
 - b. What can you say of the number of EGGS (the little rounded projections).
- Direction.* — Remove the ovary.
51. *Note.* — The OVIDUCTS are long twisted tubes with thick walls, lying at the sides of the cœlom.
- a. Are the oviducts attached to the ovary?
 - b. Describe the course of the oviducts to the surface of the body.
 - c. Into what part of the intestine do they open?
 - d. Do you find fat bodies in the female?

Drawings. — II. Alimentary tract ($\times 1$). Finish the second drawing by inserting the stomach, the small and the large intestine.

III. Urinogenital System of the Male
($\times 1$).

Label. — Kidney, ureter, bladder, cloaca, testis, fat body.

IV. Urinogenital System of the Female
($\times 1$).

Label. — Kidney, ureter, bladder, cloaca, ovary (in part), oviduct, fat body.

HOME STUDY OF MAMMAL.

(CAT OR DOG.)

1. Describe in detail the external appearance of the animal (shape, size, color).
2. Does the animal appear to be bilaterally symmetrical? Give reasons.
3.
 - a. What kind of a covering has the body?
 - b. Is this covering of uniform thickness?
 - c. Of what use is the covering to the animal?
4. Does the body show distinct regions?
5.
 - a. How many organs of locomotion are there?
 - b. Are the limbs paired or single?
 - c. Do the limbs show the same parts as do man's arm and leg?
6. Describe how locomotion is accomplished and make a diagram showing the successive positions of each appendage during locomotion.
7. What sense organs do you find?
8.
 - a. Does the animal possess the sense of touch?
 - b. Where are the organs of touch located? (Give experimental evidence.)
 - c. Are any parts more sensitive than others?
9.
 - a. Can the animal hear? (Give experiments illustrating your opinion.)
 - b. Where is the organ of hearing located?
10.
 - a. Can the animal see? How do you know?
 - b. Describe the eyes in position, size and angle of vision.
 - c. How is the eye protected?
 - d. How many lids are there?
 - e. Can the animal wink?

11.
 - a. Describe the position of the organ of smell.
 - b. What experiments did you make to determine whether the animal can smell?
 - c. How does the animal's keenness of scent compare with your own?
12. Describe the tongue in size, shape, color and character of surface.
13. How do the teeth compare in number, shape, size and position with your own?
14.
 - a. Describe experiments showing that the animal has a sense of taste.
 - b. Can the animal distinguish between 'good' and 'bad' things to eat?
 - c. Mention some things the animal likes to eat. Is it a flesh eater or a vegetarian (carnivore or herbivore)?
 - d. Where is the organ of taste? How do you know?
15. *Note.* — **INSTINCT** is a natural impulse that incites an animal to blindly perform actions essential to the existence of the animal itself or of its offspring. **INTELLIGENCE** denotes the ability to consciously adapt the means to the end: to think before acting.
 - a. Do you find in your pet any evidences of instinct? Give examples and reasons.
 - b. Have you seen any evidences of intelligence? Give examples and reasons.
16. Describe fully any tricks or curious actions done by your pet and classify them as instinctive or intelligent.

COMPARISONS BETWEEN FISH, FROG, BIRD, CAT OR DOG
AND MAN.

1. What is the general shape of the body?
2. What kind of symmetry do you find?
3. What structures are found as outgrowths of the skin?
4. What distinct regions are there?
5. Where is the skeleton located?
6. Of what material is the skeleton composed?
7. What sense organs are there?
8. What breathing organs do you find?
9. How many appendages are present?
10. What purpose do the appendages serve?
11. What are the functions of the fore limbs?
12. What are the hind limbs used for?
13. Name the parts of the fore limb.
14. Name the regions of the hind limb.
15. Are nails or claws present on fingers or toes?
16. Are teeth present?

VERTEBRA.

Materials. — Clean and dry vertebræ of man, cat or dog. Articulated human skeleton. Rulers.

1. *Note.* — The *Axis*, or central support of the body in man and the higher animals, consists of several small bones called *VERTEBRÆ*.
 - a. What disadvantages would there be in having the axis one solid mass of bone?
2. *Note.* — The larger part of the vertebra consists of a thick disc, the body or *CENTRUM*.
 - a. Describe the centrum more accurately, giving the outline from above and from the side.
 - b. Compare the 'front to back' measurement of the centrum with that taken from side to side.
 - c. Compare the 'side to side' measurement of the centrum with that taken from top to bottom.
3. *Note.* — Back of the centrum lies a ring, the *NEURAL ARCH*, which, during life, lodges the *SPINAL CORD* from which the nerves of the trunk take their origin.
 - a. What is the outline of the neural arch as seen from above?
 - b. What advantages are gained by having the delicate spinal cord placed within a bony canal?
 - c. What are the advantages of having adjacent vertebra only slightly movable on each other?
4. *Note.* — The various bony projections from the vertebra are called *PROCESSES* and the single process pointing backward is the *SPINOUS PROCESS*.
 - a. Describe the outline of the spinous process as seen from the side.
 - b. What is the shape of the free end of the spinous process?

5. *Note.* — The processes pointing sideways are the TRANSVERSE PROCESSES .

a. Describe them in number, size and shape.

6. *Note.* — The processes looking upward or downward, and forming joints with corresponding processes on the vertebra above or below, are the ARTICULAR PROCESSES.

a. Describe the articular processes in number, shape and size.

7. *Note.* — The narrow part of the neural arch just back of the centrum is the PEDICLE. The pedicle is notched above and below for the passage of the spinal nerves.

a. Which NOTCH is the deeper, the upper or the lower?

FROM HUMAN SKELETON.

8. How many vertebræ are there in the neck in man?

9. How many vertebræ bear RIBS in man?

10. How many distinct vertebræ lie beneath the ribs?

11. a. How many pieces (vertebræ) constitute the Os SACRUM?

b. What advantages are gained by having the sacral vertebræ united into a single bone?

12. How many distinct parts are there in the Coccyx (the rudimentary bone posterior to the Os sacrum)?

13. What is the total number of parts in the vertebral column of man?

14. a. Could you call man a segmented animal? Give your reasons.

b. Is the skeleton of man symmetrical?

Drawings. — I. Lateral view of a vertebra ($\times 1$).

II. View from above ($\times 1$).

Label. — Centrum, neural arch, processes (spinous, transverse and articular), pedicle, notch.

HUMAN EYE.

Materials. — A small mirror.

Direction. — Study your eye by aid of the mirror.

1. *a.* Describe the **EYEBROW** in shape, dimensions and location.
b. What is the function of the eyebrow?
2. *a.* Which eyelid is the larger?
b. What structures do you find fringing the margin of the upper eyelid?
c. Do you find the same structures on the lower lid?
d. What is the function of the eyelids?
e. What is the use of the eyelashes?
3. *Note.* — The angles between the upper and lower lids are called the **INNER** and **OUTER CANTHUS**, respectively.
a. Compare the inner with the outer canthus in shape.
4. *Note.* — The fleshy mass lying in the inner canthus is the **CARUNCLE**.
a. Describe the color and shape of the caruncle.
5. *Note.* — Just external to the caruncle is the **SEMILUNAR FOLD** (half-moon fold), representing the large winking membrane or third eyelid of the cat.
a. Describe the size and color of the semilunar fold.
b. Is it of any use in man?
6. What can you say of the number, size and color of the **BLOOD VESSELS** on the eyeball?
7. *Note.* — The white part of the eyeball is the **SCLERA**; the transparent part in front is the **CORNEA**.
a. How much of the eyeball is apparently occupied by the cornea and the sclera, respectively?

- b. Describe the outline of the cornea.
- c. Is the cornea flat?

8. *Note.* — Within the eyeball, just back of the cornea, lies a colored curtain, the *IRIS*, which exhibits a central perforation, the *PUPIL*.

Direction. — View your neighbor's eye while it is shaded by his hand and watch the pupil when the hand is suddenly removed.

- a. When is the pupil largest and when smallest?
- b. What is the advantage of this variation in size?

9. *Note.* — On the edge of the lower lid, near the inner canthus, is a little opening, through which tears pass on their way to the nose. (To see the opening more clearly turn down the inner corner of the lower lid.)

- a. Is there a similar opening on the upper lid?

10. a. Is the surface of the eyeball dry?

- b. What is the use of tears?
- c. Where do the tears go when (as in a 'cold') the tube which should carry them to the nose is wholly or partly closed?

Drawing. — The left eye ($\times 2$).

Label. — Cornea, pupil, iris, sclera, inner canthus, outer canthus, caruncle, semilunar fold, eyebrow, lids and lashes, openings of the tear ducts.

SHEEP'S EYE.

[The eyes should be cleaned and then hardened for at least a week in formol (5 per cent aqueous solution). To halve an eye, place it cornea downward on a soft board; draw a long knife through the optic nerve entrance until you feel that the knife has touched the lens; then suddenly press downward with great vigor and the eyeball will readily fall in two.]

Materials. — Half of an eye, given out in a shallow dish of water. (One specimen for every two students.)

1. What is the outline of the cut surface of the eyeball?
2. *Note.* — The outer coat of the eye consists of two parts: the opaque, white SCLERA, and the transparent CORNEA.
 - a. Describe the sclera in color, consistency, position and thickness.
 - b. Describe the cornea in the same way.
 - c. What fraction of the outer coat is occupied by the sclera and the cornea, respectively?
3. *Note.* — The middle coat of the eye exhibits two regions: the black CHOROID lying toward the back and the thicker IRIS situated just behind the cornea.
 - a. Describe the choroid in color and thickness.
 - b. Describe the iris in thickness and color, both as seen from the front and as seen from behind.
 - c. What fraction of the middle coat is occupied by the choroid and the iris, respectively.
4. *Note.* — The hole in the iris is called the PUPIL.
 - a. What is the shape of the pupil?
 - b. What is its size as compared with the iris itself?
5. *Note.* — The dead-white stalk, which pierces the coats of the eyeball at the rear, is the OPTIC NERVE.

- a. What is the diameter of the optic nerve?
 - b. Does the point of entrance of the optic nerve lie just in line with the pupil and the center of the cornea?
 6. *Note.* — The inner or nervous coat of the eye, the **RETINA**, is transparent during life, but becomes opaque after death.
 - a. Describe the retina as to thickness, consistency and extent.
 - b. What relation do you find between the retina and the optic nerve?
 7. *Note.* — In the forward part of the eyeball is found a rounded body called the **LENS**.
 - a. Describe the outline of the lens as seen in cross-section.
 - b. Which surface of the lens has the greater curvature?
 - c. Describe the consistency and the apparent structure of the lens.
 - d. Describe the position of the lens with reference to the pupil.
 8. *Note.* — The space behind the lens is filled with the **VITREOUS HUMOR**.
 - a. Describe the vitreous humor in color and consistency.
 9. *Note.* — The space in front of the lens is filled during life with a watery liquid (lymph), the so-called **AQUEOUS HUMOR**.
 - a. Which humor is present in greater quantity, the aqueous or the vitreous?
- Drawing.* — View of the cut surface ($\times 2$).
- Label.* — Sclera, cornea, choroid, iris, pupil, retina, optic nerve, lens, chamber for the aqueous humor and chamber for the vitreous humor.

PART III

EXCURSIONS



FIELD EXCURSION.

Materials. — Small card board or tin boxes in which to keep specimens collected, a few cyanide bottles and collecting nets (provided by the teacher in charge).

IN OPEN GROUND OR ALONG A ROADSIDE.

1. Describe any traces you may find of animals that live in the dirt of the road (such as ant nests or worm holes).
2. *Note.* — Large, black crickets, gray grasshoppers, beetles and ants are commonly found in such localities.
 - a. Where do you find crickets at rest? (Look under stones.)
 - b. What is the method of locomotion in the cricket?
3. How does the beetle differ in this respect?
4. Does the ant travel in the same way as the other insects just described?
5. Are any of the above insects colored like their surroundings?
6.
 - a. Find out all you can of an ants' nest without unduly disturbing it.
 - b. How many ants go and come in one minute from such a nest?
7. *Note.* — Animals living together in communities are said to be GREGARIOUS.

- a. What is the advantage of a gregarious life to the individual ant?
- 8. Do ants ever carry objects? How large may such objects be?
- 9. *Note.* — The whitish, oblong objects are the young ants taken out by the 'nurses' for light and air.
- 10. a. Do ants ever stop, and communicate with each other? If so, in what way?
b. Do ants ever fight? How do you know?
- 11. Where do you find the big, gray grasshoppers? Why?

ALONG ROADSIDES AND IN LOW GRASS.

- 12. Turn over flat stones.
 - a. Look for snakes and notice their shape, color and external appearance.
 - b. How would you describe their locomotion?
 - c. Are they protectively colored?
- 13. a. Do you find any worms under stones? In what position do you find them when first uncovered?
b. What do they do?
c. Do they seem to prefer darkness to light?
d. Are they protectively colored? How?
- 14. Do you find any insects which you have studied in the laboratory, living under stones?
- 15. *Note.* — Look for 'thousand-legs,' pill bugs or sow-bugs.
 - a. By what means are these animals protected?
 - b. How is locomotion accomplished?
 - c. Do they prefer moist or dry spots?
 - d. Would you class them as insects?

16. **Fleshy slugs (without shells) and snails (having shells) are often found under stones.**
 - a. What is the consistency of the body?
 - b. How is the body protected?
 - c. What can you say of the method and rate of locomotion?
17. **In the short grass, look for grasshoppers and green katydids.**
 - a. Are they easy to see? Why?
 - b. What means of locomotion have they?
 - c. Compare with the gray grasshoppers in this respect.
18. **Several species of spiders (tunnel weavers, running and jumping spiders) are frequently found.**
 - a. Notice the general form and position of the tunnel weavers' web.
 - b. Of what use is it to the spider? (Watch and see.)
19. **The bright-colored little spiders (very active) are crab spiders.**
 - a. Why are they so called?
 - b. How do they get their prey?
20. **How does the big, black, running spider differ in habits from those already noted?**
21. **Beetles, especially the small spotted 'lady bird,' may be found.**
 - a. Note the habitat and method of locomotion in any you may find.
22. **a. Where are the butterflies most abundant?**
 - b. Do you find any particular flowers attractive to certain butterflies?
23. **Do you find any moths? If so, where?**

IN THE LONG GRASS, WEEDS AND BUSHES.

24. Look for cocoons of moths on weeds and bushes.
Note their structure and location.
25. a. Observe, in the caterpillars found, the size, shape, color-markings and habitat.
o. Do any of the caterpillars seem to prefer certain foods to others?
(Take home some caterpillars and cocoons to keep in the breeding cage.)
26. Find the web of the large orb-weaving spider (Argiope).
 - a. Where is the web usually located?
 - b. Notice the size and shape of the web. How is it held in place? How many main supporting lines do you find?
 - c. How are the supporting lines held together.
 - d. Do you find the 'Winding stair'? If so, notice its location and structure?
 - e. Where does the spider stay when at rest?
27. a. Do you find large (female) and smaller (male) spiders in the same web?
b. How do the spiders protect their eggs and young and where do they keep such protective egg cases?
(Collect some of the egg cases to keep at home. Open one after a month: what do you see?)
28. a. Note carefully any webs in which insects have been caught, and observe all the movements of the spider from the time it sees the insect until the prey has been secured.)

- b. Does the spider always use its prey at once as food?
 - c. If you observe a spider spinning, note the part of the body from which the silk appears to come.
29. Look on golden rod for ‘yellow jackets’ (wasps). Can you find on the golden rod little beetles which resemble the wasps?
 - a. How is its color an advantage to the beetle?

IN THE WOODS.

30. Look in the trees for 'nests' of tent caterpillars.
 - a. In such a community, note the size and position on the tree. What kind of tree is preferred by the caterpillars?
 - b. Watch some of the caterpillars feeding. Is the rate of feeding rapid? Could much damage be inflicted by such means?
31. Pull off bits of bark from dead or from living trees. Look for whitish grubs (beetle larvæ).
 - a. Do you find evidences of living beetles?
 - b. How did the beetle larvæ get under the bark in the first place?
32. Among the enemies of such boring tree-destroyers, are the ichneumon-flies: wasp-like creatures with long, slender ovipositors.
 - a. Is an ichneumon-fly a true 'fly'?
33. The insect, which looks somewhat like a big mosquito, is a crane-fly.
 - a. What can you say of the legs of the crane-fly?
34. The spherical masses on some of the oak leaves are oak galls.

- a. Are the galls colored like the leaf itself?
- b. Cut open a gall. What do you find inside?
- c. How did it get there?
- d. What causes a gall to form?

ON THE SHORE OF A POND OR MARSH.

- 35. Dragon-flies are found hovering over the water.
 - a. Compare the speed of a dragon-fly with that of other insects.
 - b. How do they seem to be adapted to the life they lead?
- 36. a. In what localities do you find mosquitoes?
 - b. Look on the surface of the pond in sheltered localities for 'rafts' of eggs (very tiny).
- 37. The mosquito larvæ or 'wigglers' live in still water and come frequently to the surface of the water to get air.
 - a. Why are the larvæ called 'wigglers'?
- 38. On the surface of the pond note the 'water striders.'
 - a. Note the locomotion of a water strider.
 - b. What kind of a shadow do they cast on the bottom?
- 39. Look for big, black, water beetles.
 - a. How are they able to move rapidly through the water?
- 40. Many insect larvæ, such as dragon-flies, caddis-flies, may-flies, etc., are found at the bottom of the pond.
 - a. In general are such larvæ easily visible? Why? Is their color of advantage to the larvæ?
 - b. Do any of the larvæ make houses or cases to live

in? Describe any you may find? (The caddis-fly is most frequently found.)

41. The dragon-fly larvæ have rather square heads, strong legs and a mask-like lower lip which is used for seizing food.

(Take some home for study in the aquarium.)

42. Note any amphibious creatures you may find (such as frogs, newts, turtles, salamanders or tadpoles). How are they adapted to their conditions of life?

FIELD EXCURSION TO FORT WASHINGTON PARK.

ON THE ROAD TO THE HILL (DEPOT LANE).

1. Along the roadside notice the weeds.
 - a. Are their fruits abundant?
 - b. Would the number of fruits account in any degree for the abundance of weeds?
2. Find the clot-burs.
 - a. Where and how do they grow?
 - b. Do they survive the winter?
 - c. Are the seed-vessels of use to the plants? How?

ON THE DAMP ROCKS BY THE ROAD.

3.
 - a. What can you say as to the twining stems running over the rocks?
 - b. What kind of roots do they have?
 - c. What can you say of the number and the probable function of these roots?

IN THE PRIVATE GROUNDS TO THE RIGHT.

4. Notice two types of tree trunks: EXCURRENT and DELIQUESCENT.
 - a. How many examples of each do you find?

ON THE HILLSIDE.

5. *a.* By what characters of bark and leaves could you distinguish the birch trees (on the right hand side of the road)?
6. Notice (on fences and trees) the small bracket fungi.
 - a.* Are they found on healthy trees?
7. On rocks along the road may be found lichens.
 - a.* What shape do you find in these plants? Do all specimens have the same form?
 - b.* Do lichens contain chlorophyll?
 - c.* Is the color the same throughout the plant?
 - d.* Do you notice any change in the surface of the rock near the growing lichens?
 - e.* What part do lichens appear to play in Nature?
8. Near the entrance of the park is seen the large ex-current trunk of a Lombardy poplar.
 - a.* What are the characters by which you could know this tree?

IN THE PARK.

9. The group of tall trees just inside the park gate consists of tulip trees.
 - a.* How could you distinguish them?
 - b.* Why do the trunks run up so far without branching?
 - c.* Why do trees growing in dense forests generally bear leafy branches only near the top?
 - d.* What can you say of the leaf of the tulip tree?
10. *a.* Do you find any green slime (*Pleurococcus*) on these trees?

ALONG EASTERN EDGE OF RAILROAD CUT. 179

- b.* How would you characterize a chestnut tree with regard to growth, bark and leaves?
- 16. Near-by are several other trees, such as oak, ailanthus and sassafras.
 - a.* How many different forms of leaf can you find on a single sassafras plant?
 - b.* Find the chief characters of each of the above plants.
- 17. Note the dense growth of cat briar.
 - a.* How is the cat briar especially adapted to its mode of life?
 - b.* Of what use are the thorns?
 - c.* Of what use are the tendrils?
 - d.* In what way are the buds protected?
- 18. Among the rocks are found several species of evergreens: as spruce, pine and cedars. With the aid of the teacher distinguish between these trees.
 - a.* Why are these trees called 'evergreens'?
 - b.* Are there any evidences of their being hardy trees?
 - c.* By what single character could you distinguish the various kinds?

ALONG THE EASTERN EDGE OF THE RAILROAD CUT.

- 19. Look on the exposed rocks for beds of moss.
 - a.* Do you find any large plants close by?
 - b.* What reason can you give for the size of the neighboring plants?

- c. Do you find fruiting moss plants?
- d. How may you distinguish male, female and sterile specimens?

ON THE ROCKY LEDGE NEAR THE BRIDGE.

- 20. a. What is the general character of the vegetation?
- b. What effect is produced on the rocks by the growth among them of trees?
- c. Note the characters of stem and leaf in the 'mountain' laurel. Why is the plant so called?

ON THE SIDES OF THE GULLY ON THE NORTH.

- 21. Observe the stout branches of witch hazel.
 - a. Would you call the plant a shrub or a tree? Why?
 - b. Is the plant in fruit? Do the trees near-by bear fruit at this time?
 - c. Is the plant in flower? Do plants generally bear flowers at this season?

ON THE EXPOSED RIDGE RUNNING NORTH-WARD.

- 22. What kind of trees do you find? Why?

ON THE WALLS OF THE 'CUT.'

- 23. a. What can you say of the number of plants growing in this place?
- b. What explanation can you offer for the observed facts?
- c. About how many kinds of plants are to be found here?

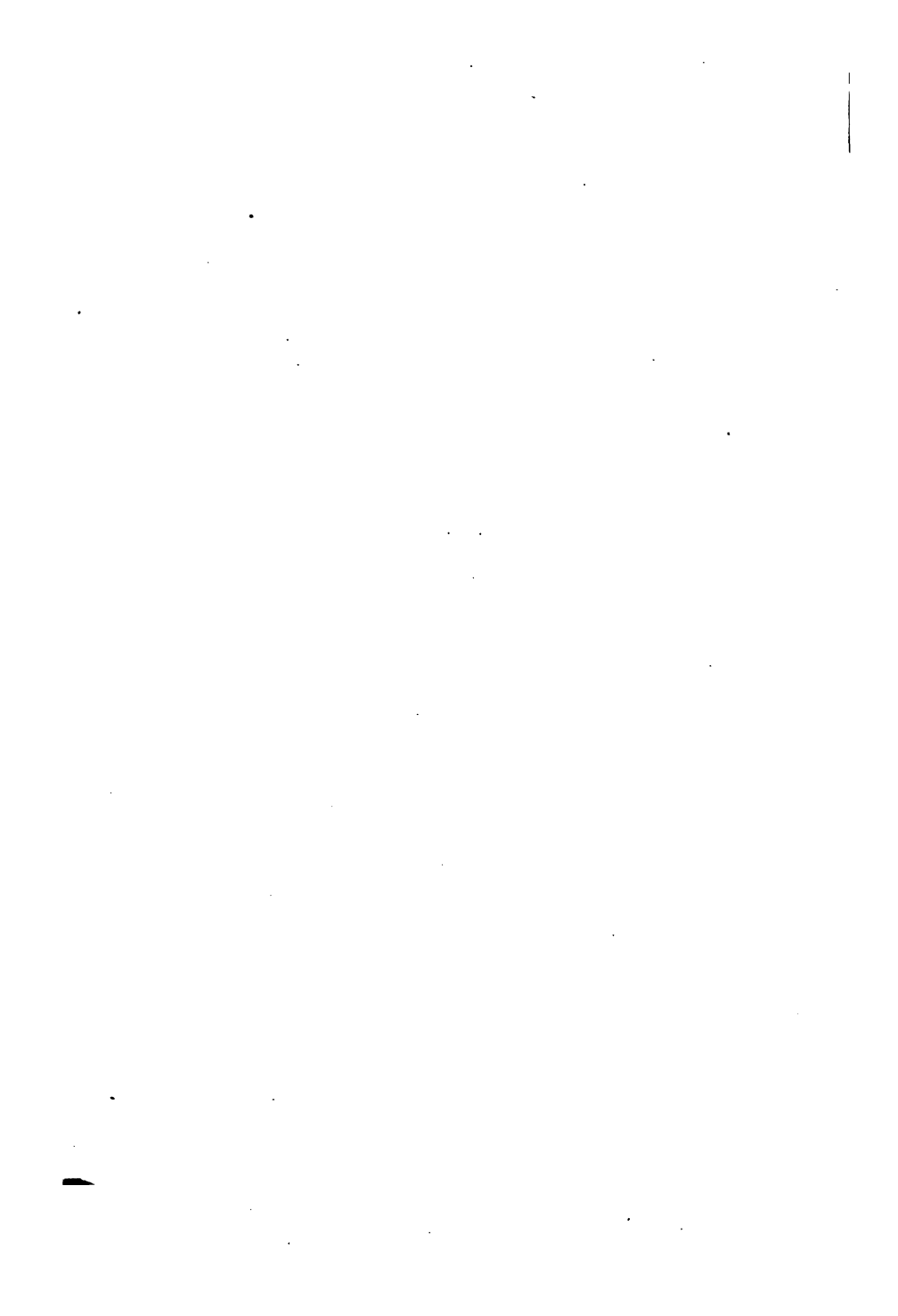
ON THE WEST SIDE OF THE 'CUT.'

24. Note the abundant staghorn sumach.
 - a. Why is the name 'staghorn' applied to this plant?
 - b. What kind of leaf scars do you find?
 - c. How are the buds protected?
25. Note the tree with four main trunks united at the base.
 - a. Do all its trunks appear healthy?
 - b. Can you discover on the dying trunk any causes for its decay?
26. Count the number of young oaks growing within a radius of ten paces from the parent tree.
 - a. What would happen if all these young plants grew up?
 - b. Which has the advantage at first, the young plant or the old?
 - c. What conditions prevent the overcrowding of plants?
27. Notice the wild grape vines.
 - a. By what means is the plant enabled to climb?
 - b. What advantage does the climbing habit give the plant?
28. Observe the line of earthworks thrown up during the War of the Revolution.
 - a. Were the trees now found in the earthworks there at the time the works were thrown up?
29. Note the dense growth of wild honeysuckle.
 - a. How does the plant climb?
 - b. Does it have tendrils?
30. Observe a small dead tree densely entwined with honeysuckle.
 - a. What probably caused the tree's death?

31. On the dripping rocks near the river observe the plants, noting the kinds, the number of forms and the general color.
32. *a.* On the dry rocks near-by are numerous plants.
What kind of plants do you find?
b. What is the general color of the plants?
c. How are they adapted to their environment?
33. On the rocks at the water's edge is found rockweed.
a. How is the plant attached to the rocks?
b. Is it always under water?
c. Would it readily become dry at low tide?
34. Observe the general inclination taken by the tree trunks on the slope toward the north. How can you account for the peculiar form of these trees?

PART IV

EXPERIMENTS



EXPERIMENT I.*

PROBLEM. — *To prepare oxygen and test its properties.*

DATE. —

Materials. — Large test tube, long splinter of wood, mercuric oxide, Bunsen burner.

Experiment. — Heat the mercuric oxide in the tube and, when a fair amount of the solid has been vaporized, suddenly plunge the splinter, with a spark on the end, into the tube.

Observation. — What happens to the spark?

Conclusion. — What is the influence of oxygen on combustion as compared with the effect of ordinary air?

* Experiments marked with a star may be performed by the teacher and reported by the class.

EXPERIMENT 2.*

PROBLEM. — *To study the union of magnesium wire with oxygen.*

DATE. —

Materials. — Balance, magnesium wire, pair of forceps, Bunsen burner.

Experiment. — Weigh the piece of magnesium wire, then holding one end of it with the forceps, light the other end at the Bunsen flame. Weigh the resulting ash.

Observation. — Describe what happens to the wire, noting the appearance before and after burning.

Conclusions. — 1. What do you infer from the change in weight?

2. What changes accompany the union of oxygen with other substances?

EXPERIMENT 3.*

PROBLEM. — *To study deoxidation or reduction.*

DATE. —

Materials. — Piece of charcoal, a little litharge, a blow-pipe, a Bunsen burner.

Experiment. — Heat the litharge (oxide of lead) on the charcoal in the inner blowpipe flame.

Observation. — What substance appears on the charcoal?
What changes take place in the litharge?

Conclusions. — 1. Is it easy to separate oxygen from substances combined with it?
2. What was necessary in the present case in order to separate the oxygen from the lead?

EXPERIMENT 4.*

PROBLEM. — *To test for carbon in food stuffs.*

DATE. —

Materials. — Piece of platinum foil, Bunsen burner, pair of forceps, portions of sugar, starch, etc.

Experiment. — Slightly burn the material to be tested, on platinum foil, over the Bunsen flame.

Observations. — Note the resulting odor and color.

Conclusions. — 1. What is the color of ordinary carbon or charcoal?

2. Describe the color of starch and of sugar when slightly burned.

3. Do these substances contain carbon?

EXPERIMENT 5.*

PROBLEM. — *To test the properties of carbon dioxide.*

DATE. —

Materials. — Erlenmeyer flask with glass delivery tube, water trough, glass jars, square pieces of glass to cover the jars, lumps of marble, hydrochloric acid, lime water, candle on a wire.

Experiment. — Collect over water several jars of carbon dioxide.

- a.* Insert the lighted candle into the gas.
- b.* Pour lime water into a jar of the gas and shake thoroughly; or let the gas bubble through lime water.

Observations. — What happens in Experiments *a.* and *b.* respectively?

Conclusions. — 1. What is the effect of carbon dioxide on a flame?
2. What effect has carbon dioxide on lime water?

EXPERIMENT 6.*

PROBLEM. — *To determine some of the conditions under which a candle flame will continue, and to test the substances produced by a flame.*

DATE. —

Materials. — Glass tumbler, small piece of candle with a string attached, square piece of glass to cover the tumbler, lime water.

Experiments. — Place the bit of candle in the tumbler and, after lighting the wick, cover the tumbler with the square piece of glass. After the experiment is over, carefully draw out the candle by means of the string and pour some lime water into the tumbler.

Observations. — What happens to the flame? What is deposited on the glass? What happened to the lime water?

Conclusions. — 1. What conditions are necessary for the continuance of a flame?
2. What substances are produced by a candle burning in air?

EXPERIMENT 7.*

PROBLEM. — *To determine some of the materials given out by an animal in its breath.*

DATE. —

Materials. — A clean glass plate, a beaker of lime water, a glass tube.

Experiments. — *a.* Breathe on the glass plate.
b. Blow the breath through lime water by aid of the glass tube.

Observations. — *a.* What substance do you find on the glass plate?
b. What happens to the lime water?

Conclusions. — 1. Compare the result in *a.* with that obtained when the candle burned in the tumbler. INFERENCE?
2. Compare the result in *b.* with that obtained with the candle flame. INFERENCE?

EXPERIMENT 8.*

PROBLEM. — *Tests for food stuffs.*

DATE. —

Materials. — White of egg, starch, grape sugar, a few peanuts, nitric acid, ammonium hydrate, iodine solution, Fehling's solution, thin paper, benzol, test tubes, Bunsen burner.

- Experiments.* —
- a. Heat some white of egg in a test tube.
 - b. Treat some white of egg with nitric acid; pour off the acid and add ammonium hydrate.
 - c. Treat starch with iodine solution.
 - d. Heat solution of grape sugar with Fehling's solution.
 - e. Grind peanuts in a mortar with benzol, filter and let the benzol evaporate; put some of the residue on thin paper.

Observations. — Tell in each case what happens.

EXPERIMENT 9.

PROBLEM. — *Do dry seeds absorb water?*

DATE. —

Materials. — Dry peas, small bottle and cork, paste and paper.

Experiment. — Fill the bottle half full of dry seeds and pour over them enough water to almost fill the bottle. Cork the vessel and paste a strip of paper on the outside to show how much space the seeds occupy.

Observations. — Next morning note whether the seeds occupy the same amount of space. Is the water still visible?

Conclusion. — Explain what has happened.

EXPERIMENT 10.

PROBLEM.—*The effect of moisture on germinating seeds.*

DATE. —

Materials. — Two tumblers and one sauce dish, blotting paper, fifteen peas or beans.

Experiment. — Soak the seeds over night in water. Place moist blotting paper or sawdust in the vessels, pack it down well and then put five seeds in each. Number the glasses 2 and 3 respectively, and let 1 be the saucer. Place 1 in a warm, dry room and moisten once a day with half a teaspoonful of water. Place 2 and 3 in the same room with 1, but give 2 a tablespoonful of water each day and keep the seeds in 3 just covered with water all the time. Cover 2 and 3 with blotting paper and leave 1 uncovered.

Observations. — Examine the seeds every day for ten days. Make daily notes of the rate of growth and the number of seeds that develop in 1, 2 and 3. Record your results in tabular form. Draw a well developed specimen from each dish at the end of your experiment.

Conclusions. — What influence will a large, a moderate and a small amount of water, respectively, have upon germinating seeds?

EXPERIMENT II.

PROBLEM. — *The effect of temperature upon germinating seeds.*

DATE. —

Materials. — Three tumblers or wide-mouthed bottles, blotting paper or sawdust, fifteen peas or beans.

Experiment. — Soak the seeds over night. Put a layer of moist blotting paper or saw dust in the bottom of each glass. Place five seeds in each tumbler, covering it with blotting paper. Put one glass outside on the window ledge,* one in the living room and one near the radiator or kitchen stove. Water each vessel moderately every day.

Observations. — Examine the seeds daily. Make a table to show the number of seeds that sprout each day in each glass. Sum up the total number sprouted in each tumbler at the end of the experiment. Note any other changes that have taken place.

Conclusions. — 1. What effect do different degrees of temperature have on developing seeds?

2. What range of temperature is the most favorable for peas or beans?

* This experiment is generally performed in cold weather.

EXPERIMENT 12.

PROBLEM. — *The effect of air upon germinating seeds.*

DATE. —

Materials. — A few peas that have germinated in the previous experiments, a glass bottle with tight cork, sealing wax, boiled water.

Experiment. — Fill the bottle with cold boiled water, then put in the seeds, which should have germinated so far as to show the hypocotyl. Cork the bottle tightly so as to exclude all air bubbles and seal with wax.

Observations. — Note carefully every day for ten days whether further growth takes place.

Conclusion. — What effect does lack of air have upon germinating seeds?

DEMONSTRATION. — Soak fifty peas. Put twenty-five into a flask which is left open and the remainder into a similar flask which is tightly corked. Leave both flasks in a moist, warm place and note the effect upon germination.

EXPERIMENT 13.*

PROBLEM. — *Is carbon dioxide produced by germinating seeds?*

DATE. —

Materials. — A tall jar with a glass stopper, a cupful of peas or beans, a candle.

Experiment. — Place the dry peas in a jar and pour in enough water to cover them. Cover the jar tightly.

Observation. — After three days carefully take off the cover of the jar and insert a lighted candle. Note what happens.

Conclusion. — What has been formed in the jar?

EXPERIMENT 14.*

PROBLEM. — *Do germinating seeds produce heat?*

DATE. —

Materials. — Two tall jars with cork stoppers, two thermometers, a quantity of peas.

Experiment. — Half fill one jar with soaked peas which have been killed by heat; half fill the other with germinating peas. Pass a thermometer through the cork of each jar so that the bulbs are equally covered by the seeds.

Observations. — Observe the temperature in the jars every day, for three or four days.

Conclusions. — Do you find any difference in the temperature of the two jars? How do you explain this difference?

~~EX~~PERIMENT 15.

PROBLEM. — *What are the effects of light on germinating seeds?*

DATE. —

Materials. — A tumbler and a cup, blotting paper or sawdust, ten peas.

Experiments. — Soak the peas over night. Place two or three layers of moist blotting paper or sawdust in the bottom of each vessel and then put in five peas. Place the vessels, covered with blotting paper, side by side in a warm room near the window. Water them every day.

Observations. — Examine the seeds daily for ten days and note any changes that take place. Make a table showing the total number of seeds germinating on each day in either vessel. At the end of a week count the number sprouting in each. Note the changes of every kind that may have occurred.

Conclusions. — 1. Does light influence the rate of germination?
2. Does it in any other way affect the young seedling?

EXPERIMENT 16.

PROBLEM. — *What becomes of the three elements of the embryo in the bean, pea and corn?*

DATE. —

Materials. — Three cigar boxes half filled with moist sawdust; peas, beans and corn.

Experiment. — After soaking the seeds over night, plant them in the boxes and water them every day. Keep in a warm, sunny room if possible.

Observations. — As soon as any parts have risen above the surface, note the date and make a drawing of the part visible. Do this daily, with the best developed seedling of each kind, for fourteen days. On the fifteenth day take up one of each kind of seedling and draw the whole plant.

Conclusions. — What becomes, in the bean, pea and corn, of cotyledons (or endosperm), hypocotyl and plumule, respectively?

EXPERIMENT 17.

PROBLEM. — *To determine the function of the cotyledons.*

DATE. —

Materials. — Six germinating peas, wide-mouthed bottle or tumbler, piece of mosquito netting.

Experiment. — Take six germinating peas from Experiment 16. Fill the bottle or tumbler with water and tie the netting over its mouth. With a sharp knife carefully remove the cotyledons from three of the peas; then place all six seedlings on the netting with the roots hanging in the water. Be careful to keep the jar always full of water and in a moderately warm place.

Observations. — Note daily the appearance of the peas for ten days. Describe the rate of growth in the normal and the mutilated pea. Draw a normal pea and one deprived of its cotyledons, as seen at the end of ten days.

Conclusions. — What do you conclude as to the use of the cotyledons?

EXPERIMENT 18.

PROBLEM. — *Of what use is the endosperm to the embryo of corn?*

DATE. —

Materials. — Six grains of corn already sprouted (from Experiment 16), wide-mouthed bottle or tumbler, mosquito netting.

Experiment. — Fill bottle or tumbler with water and tie mosquito netting over the mouth. Carefully remove, from three grains, all of the endosperm except the part immediately surrounding the embryo, and leave the other specimens entire. Place the six on the netting with the roots in the water. Keep in a warm place, taking care that the bottle is always full.

Observations. — Watch carefully the condition of the six specimens for ten days and then describe the amount of growth in each case.

Conclusions. — What do you conclude as to the use of the endosperm?

EXPERIMENT 19.

PROBLEM. — *How do gravity and water, respectively, influence the growing seed?*

DATE. —

Materials. — Radish seeds; a glass tumbler; a piece of cigar-box wood narrower than the tumbler, soaked in water for forty-eight hours.

Experiment. — Sprinkle the seeds over one surface of the wet board and keep them well moistened until they stick fast.

A. Place the wood (with the seeds on the under surface) in the tumbler at a sharp slant and keep the seeds well moistened. Let the seeds grow for several days.

Observation. — **A.** In what direction do the seeds grow with reference to the surface of the wood?

Experiment. — **B.** When you have finished Experiment **A**, cut off a small piece from either end of the wood and wedge the remainder (with the seeds still downward) into the tumbler at a very slight slant. Moisten as before.

Observation. — **B.** In what direction do the roots now grow?

Conclusions. — Explain the direction taken by the roots in Experiments **A** and **B**.

EXPERIMENT 20.*

PROBLEM. — *To measure the force exerted by a root in growing downward.*

DATE. —

Materials. — A large vial (*A*) and a much smaller one (*B*), each fitted with a cork, (*a*) and (*b*) respectively (the vials should each be of uniform diameter throughout); four short insect pins; a pea seedling.

Experiment. — Fasten the seedling near the center of the under side of cork (*a*) by means of a pin, so that the root will point directly downward. Burn a narrow and shallow depression in the top of cork (*b*) and pass three pins, 120° apart, into the sides of the cork to such a depth that the cork and pins together, when placed in vial (*A*), will move without friction. Put a little water in vial (*A*), cork vial (*B*) and float it on the surface of the water in (*A*). Drop water gradually into vial (*A*) until the tip of the root of the seedling (as the cork of vial (*A*) is put into place) will just fit into the depression on the top of cork (*b*), without causing the vial (*B*) to sink. By fastening a label on the outside of vial (*A*), mark the level of the water. Now allow the seedling to grow for one or two days. Paste another label on vial (*A*) to show the level of the water at the end of the experiment. Carefully remove cork (*a*) leaving vial (*B*) in place. With great care, by putting weights on the cork of vial (*B*), determine the

pressure necessary to produce the displacement brought about by the growing root.

Observation. — What weight is necessary to sink vial (B) to the level reached under the pressure of the growing root?

Conclusion. — How much pressure, measured in terms of weight, was exerted by the root of the pea seedling, growing under the given conditions?

EXPERIMENT 21.

PROBLEM. — *The influence of light on young plants.*

DATE. —

Materials. — Peas or beans, sawdust, a cigar box with a hole cut in one of the small ends.

Experiment. — Place some moist sawdust in the cigar box, making a layer about one-half inch in depth. Soak seeds over night and plant them in the sawdust. Shut the lid and place the box near a window with the hole toward the light. Water every day.

Observations. — Open the box daily for ten days and note the rate and direction of growth in the seedlings. Do those near the light grow better? Is there any difference in color between those near and those farther away from the light?

Conclusion. — What effect does light have on young plants?

EXPERIMENT 22.*

PROBLEM. — *To determine the point of most rapid growth in the root.*

DATE. —

Materials. — Growing pea seedlings, fine pen or brush and India ink.

Experiment. — In seedlings which have a root about half an inch in length, make, at equal intervals (about two millimeters), five or six marks on the root; then allow the seedlings to grow undisturbed for a few days.

Observations. — At the end of five days describe the position of the marks on the roots. Are the marks at the same distance apart as at first?

Conclusions. — Do all parts of the root grow with the same rapidity? Where is the region of most rapid growth?

EXPERIMENT 23.*

PROBLEM. — *Will fluids pass through a moist animal membrane?*

DATE. —

Materials. — Small battery jar, glass rod, bladder, string, copper sulphate solution, iron nails, potassium ferro-cyanide solution, test tubes.

Experiment. — Partly fill the battery jar with water. Fill the bladder with copper sulphate solution, tie it tightly and suspend it in the jar by fastening it to the glass rod placed over the mouth. Place the nail in the water. 1. Test the water outside with potassium ferro-cyanide. 2. Leave the jar for twenty-four hours and again test the water. Observe the iron nail.

Observations. — 1. What result is obtained at first?
2. What result is obtained next day?
What change do you note in the iron nail?

Conclusions. — Explain what you have seen.

EXPERIMENT 24.*

PROBLEM. — *Will liquids rise in a stem?*

DATE. —

Materials. — A strongly growing plant of sunflower, nettle or dahlia (in pot); glass tubing of the same diameter as the stem of the plant; rubber tubing; iron stand.

Experiment. — Cut off the stem of the plant near the ground and closely fasten the glass tubing to the stump by means of the rubber tubing. Water the earth about the plant frequently.

Observations. — Observe the plant several times during the next twenty-four hours. What happens?

Conclusions. — What is the source of the observed liquid; how does it get to its present position (see Experiment 23); where would the liquid go, in an uninjured plant?

EXPERIMENT 25.

PROBLEM. — *What causes the rigidity of non-woody stems or roots?*

DATE. —

Materials. — Carrot, granulated sugar.

Experiment. — Hollow out a large depression in the top of a carrot. Fill the space with granulated sugar; then put the carrot away in an upright position for a day or two.

Observations. — Note carefully at the end of the time the relative dryness of the carrot and the sugar. Which has lost water and which gained it?

Conclusion. — How do you account for this result? How would you answer the given problem?

EXPERIMENT 26.

PROBLEM. — *What is the use of the skin of the potato?*

DATE. —

Materials. — Two potatoes of nearly equal weight, scales, knife.

Experiment. — Record the weight of each potato, then peel one and weigh the skin. Put the two potatoes side by side in a warm, dry place.

Observations. — At the end of four days re-weigh each potato, adding, in the case of the peeled potato, the weight of the skin. Compare the weights with those previously obtained.

Conclusion. — Explain fully what has happened. In what way is the skin of value to the potato?

EXPERIMENT 27.

PROBLEM. — *Does water pass off through the leaves?*

DATE. —,

Materials. — A cut branch of a geranium or hydrangea,
jar of water, perforated cardboard, glass tumbler.

Experiment. — Place the branch so that the lower end
will protrude through the piece of cardboard
into the water; then seal the joint tightly with
wax. Invert the tumbler so as to cover the
leaves.

Observations. — After a few hours observe the condition
of the tumbler.

Conclusions. — Explain what you find.

EXPERIMENT 28.*

PROBLEM. — *Through which surface of a leaf does evaporation take place most freely?*

DATE. —

Materials. — Two fresh leaves of 'rubber plant' or other plant with large leaves, paraffin or grafting wax, sweet oil or vaseline.

Experiment. — Carefully cover the cut ends of the petioles in each leaf with grafting wax so that no moisture can escape; cover the upper surface of one leaf and the lower surface of the other with sweet oil or vaseline. Hang both leaves in a sunny window.

Observations. — Does any difference in the appearance of the leaves become evident?

Conclusions. — What are your conclusions?

EXPERIMENT 29.*

PROBLEM. — *Under what conditions is starch formed in leaves?*

DATE. —

Materials. — Growing nasturtium or hydrangea, thin disks of cork, insect pins, methyl alcohol, iodine solution.

Experiment. — Place the plant in full sunlight. Select two or three large, well-lighted leaves, and shut off the sunlight from part of their surface by pinning together disks of cork placed on either side of the leaves. After several hours of sunlight, remove the leaves and wash them in several changes of methyl alcohol to remove the chlorophyll. Test the leaf for starch.

Observation. — What is the result?

Conclusions. — 1. What portions of the leaf formed starch?
2. Under what conditions is starch formed?

EXPERIMENT 30.*

PROBLEM. — *What gas does a green plant give off in sunlight?*

DATE. —

Materials.—A glass battery jar, glass funnel, test tube, iron stand and clamps, fresh Elodea or Spirogyra.

Experiment. — Invert the funnel under water over some growing Elodea or Spirogyra and fasten it in place with the clamps. Place over the inverted funnel an inverted test tube filled with water. Leave the apparatus in sunlight for several hours.

Observation. — Note the bubbles which arise from the plant and are collected in the test tube. Make a test of this gas with a glowing match end. What happens?

Conclusion. — What gas has been formed and what is its source?